BREAKTHROUGH
National Centre For Climate Restoration

DISCUSSION PAPER

Warming has reached 1.5°C. What does that mean for climate advocacy?

AUGUST 2025

Summary

- Global warming has reached 1.5˚C and the rate of warming is accelerating.
- On the present path, Earth will heat by 3+˚C. The aerosol "Faustian bargain" means that emissions reductions are unlikely to reduce the rate of warming in the near term.
- While much of the climate community remains committed to the 1.5˚C Paris goal, this target is fundamentally flawed: it does not represent a safe boundary, will not prevent large-scale Earth system elements passing tipping points, nor does it mark a point of system stability.
- Too often, climate strategy has been reduced to a "triage politics" of selecting what to save and what to abandon. Policies of large "overshoot" of 1.5˚C make assumptions about the ability to restore Earth systems that are not valid.
- Advocates now face difficult questions, including whether a safe climate can be achieved if climate actions involve only the elimination of greenhouse gas emissions.
- An alternative goal is a return to the Holocene conditions of <0.5˚C.
- This demands a three-lever strategy — simultaneously pursuing zero emissions, large-scale carbon drawdown, and research into safe short-term cooling methods.

> "Today the level of greenhouse gases in the atmosphere is already so high that rapid emissions reduction is no longer sufficient to avoid an unmanageable future for mankind. We also must have the capability to remove GHGs at scale from the atmosphere, and to repair those parts of the climate system, such as the Arctic Circle, which are passing or have passed their tipping point."
> **— Sir David King**, former UK Chief Scientist & founder, Centre for Climate Repair [1]

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[1] breakthroughonline.org.au/dor

Warming has reached 1.5°C. What does that mean for climate advocacy?

> "Believe in truth. To abandon facts is to abandon freedom. If nothing is true, then no one can criticise power, because there is no basis on which to do so. If nothing is true, then all is spectacle. The biggest wallet pays for the most blinding lights."
>
> — Timothy Snyder, *On tyranny: Twenty lessons from the twentieth century* (The Bodley Head 2017)

With world politics turned upside down, climate policy-makers and advocates are reviewing strategies and preparing for the next policy-making conference in Belém, Brazil in November 2025. Warming has hit 1.5°C in practical terms, there is new urgency, and a fateful decision must be made.

Part 1: The current situation

The physical world is heating up at an accelerating rate, as the *New York Times* recently illustrated (Figure 1),[2] and discussed in more detail at the Climate Brink.[3] That faster rate of warming will continue because Earth's Energy Imbalance is increasing: it is trapping much more heat than climate models forecast, and the rate of increase has doubled in 20 years.[4]

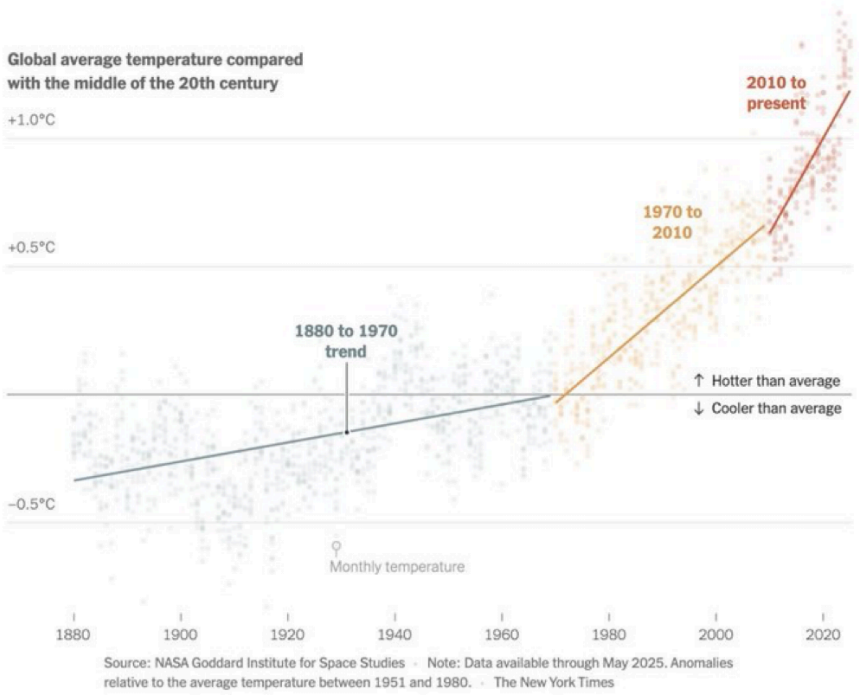

Figure 1: Global average temperature compared with the middle of the 20th century (NYT)

And the world of climate policy-making and advocacy is in tumult. Big oil and gas are fast backtracking on reduction commitments, and planning increased production to 2050.[5] Big banks and

[2] nytimes.com/2025/06/26/climate/climate-heat-intensity.html
[3] theclimatebrink.com/p/the-great-acceleration-debate
[4] theconversation.com/earth-is-trapping-much-more-heat-than-climate-models-forecast-and-the-rate-has-doubled- in-20-years-258822
[5] smh.com.au/environment/climate-change/we-should-abandon-the-fantasy-oil-giants-scale-back-climate-pledges-20240327-p5ffoz.html

big business are abandoning previous climate net-zero commitments,[6] in part because the Covid mobilisation and the Ukraine and Middle East wars have reduced focus on climate policy. There is the prospect of global emissions dropping only 10–20% by 2050 on the current policy path.[7]

Physically, emissions from fossil fuels are still rising,[8] which means that renewable energy is not yet *replacing* fossil fuels, but rather *adding* to the fossil-fuelled energy supply. The fossil-fuel intensity of production is decreasing, but energy demand is increasing rapidly for sectors such as AI, crypto and cloud computing, and in India and China. So, in absolute terms, the world is not yet decarbonising.

The deployment of renewable energy and large and small batteries is accelerating, and they are now way down the cost curve compared to coal and gas. But in sectors other than electricity, the use of fossil fuels is rising.

That path of continuing high emissions — together with a growing Earth Energy Imbalance, reduced aerosol levels (see page 8), and decreases in the efficiency of carbon stores — means warming is likely to proceed at a rate of 0.25 to 0.3˚C per decade for the next two or three decades. In this scenario, global average warming will trend to 2˚C around 2040-45. The UN Intergovernmental Panel on Climate Change's (IPCC) warming projections of 1.5 to 2˚C by 2050 on which policy-makers and many NGOs have relied are now clearly out of date.

A clear majority of scientists expect warming of more than 3˚C, and 82% expect to see catastrophic impacts of climate change in their lifetime, according to a 2021 survey by the journal *Nature*.[9] A survey of 380 IPCC scientists by *The Guardian* in 2024 found 80% foreseeing at least 2.5˚C of global heating, and half of them 3˚C or more.[10] Many of the scientists envisage a "semi-dystopian" future, with famines, conflicts and mass migration, driven by heatwaves, wildfires, floods and storms of an intensity and frequency far beyond those that have already struck.

The last two climate policy-making Conferences of the Parties (COPs) were hosted by petrostates and Donald Trump has withdrawn the world's largest economy (or second largest, depending on the mode of analysis) from the COP process and the 2015 Paris Agreement. Climate denial seems *de rigeur* for the new authoritarian politics, as well as petrostates. There is geopolitical mayhem, with more attention on defence spending and traditional concepts of national security, and less attention — and less money for — climate mitigation, human security and equitable financing of both the transition and adaptation.

Part 2. The climate advocacy position

For a quarter of a century, climate policy-makers have speculated about the maximum climate damage that civilisation and the Earth system can tolerate and adapt to. How close to the edge of the climate cliff can we stand, without falling to our death? Three degrees? Two? One-and-a-half? Clearly the goal pursued is not the provision of "maximum protection" to the most climate vulnerable,[11] but rather some poorly-informed notion of maximum acceptable damage.

As climate advocates — and especially the large, professional advocacy groups and networks — revise strategies and prepare for COP30 and the UNFCCC members' 10-year update on Nationally

[6] bloomberg.com/news/features/2025-06-12/climate-pledges-dropped-by-coca-cola-bp-hsbc-as-planet-heats-up
[7] unep.org/resources/production-gap-report-2023
[8] csiro.au/en/research/environmental-impacts/emissions/Global-greenhouse-gas-budgets/Global-carbon-budget
[9] nature.com/articles/d41586-021-02990-w
[10] theguardian.com/environment/article/2024/may/08/world-scientists-climate-failure-survey-global-temperature
[11].breakthroughonline.org.au/_files/ugd/148cb0_c039398da2784c45b721dc79419acc81.pdf

Determined Contributions (NDCs), the outlines of their advocacy position is emerging. Whilst there is not homogeneity, some common features for mitigation policy appear to be:

- Stay focused on the lower end of the Paris goal of 1.5˚C; work to keep 1.5˚C "within reach"; and similar language.[12] ClimateAnalytics says "the 1.5˚C threshold represents an ethical and moral boundary".[13]
- Below 1.5˚C is still technically possible, with temperature overshoot and the return to 1.5˚C by 2100 as a goal;
- The phrase "every fraction of a degree (above 1.5˚C) matters" is frequently used, reflecting the significant risks associated with 2˚C compared to 1.5˚C. But there is no mention of the big difference between 1˚C and 1.5˚C, for example;
- Ending fossil fuel use;
- Targets for developed economies of "net zero" by 2035;
- Recognition that there is a lack of ambition and urgency, especially in revising NDCs;
- Polluters should pay for mitigation and climate finance; and
- The goal of advocacy "must be based on climate justice and science".[14]

Positions vary on whether warming has already hit 1.5˚C, and whether 1.5˚C is a safe target or not (generally the latter is not discussed). Some refer to (illusory) carbon budgets for 1.5˚C. Most large traditional climate advocacy organisations and networks are actively opposed to research and testing of climate interventions such as direct cooling, or are silent on the issue.

In describing this paradigm in this discussion paper, the focus is on the large, professional advocacy NGOs, whilst recognising that there are some advocates and organisations who take a stronger position, but they appear to be a small minority. I hope I am wrong about that.

Part 3. The 1.5 degrees advocacy conundrum

- **1.5˚C has become the policy-making target**

Until 2015, climate-policy making and advocacy was focused on the 2˚C goal, which was seen as appropriate to "prevent dangerous anthropogenic interference with the climate system" (Article 2 of the UNFCCC). But why was 2˚C ever considered a reasonable goal? Answering that question — it wasn't science-based, but first proposed by an economist[15] — may provide insight into why 1.5˚C isn't a reasonable goal either.

At the Paris COP in 2015, the overarching goal adopted was to hold "the increase in the global average temperature to well below 2˚C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5˚C above pre-industrial levels".[16] Since the Paris Agreement, the focus of advocates has been 1.5˚C.

[12] For example: greenpeace.org/international/press-release/75740/dire-warning-1-5c-goal-urgent-climate-action; explore.panda.org/climate
[13] climateanalytics.org/publications/latest-science-on-the-1-5-c-limit-of-the-paris-agreement
[14] climatenetwork.org/resource/briefing-sb60/
[15] climate.mit.edu/ask-mit/why-did-ipcc-choose-2deg-c-goal-limiting-global-warming
[16] https://unfccc.int/process-and-meetings/the-paris-agreement

- **The flawed benchmark of 1.5˚C**

Sir David King, the former UK Chief Scientist and advisor to three (Labour and Conservative) governments, reflected on his work with AOSIS on 1.5˚C in Paris in 2015. *The Independent* journalist Donnachadh McCarthy reported that King "astounded me by saying he now realised this was wrong, and believes the passing of the Arctic tipping point has been reached... He said the *1.1˚C rise that we already have is too dangerous* — and candidly admitted he believed US climate professor James Hansen had been right after all in 1988, when he warned the US Congress that we should not pass 350 ppm CO_2 (parts per million carbon dioxide). We have now breached 415 ppm and are heading fast towards 500 ppm, Sir David said" (emphasis added).[17]

This is widely understood. The NGO 350.org was explicitly established in 2008 on the view that what was safe was < 350 ppm and < 1˚C, a position based on the work of former NASA climate chief James Hansen, sometimes referred to affectionately as the "godfather" of modern climate science.

Likewise, in "A safe operating space for humanity", Rockstrom et al. (including Hansen and Will Steffen), proposed that "human changes to atmospheric CO_2 concentrations should not exceed 350 ppm".[18]

But in current mainstream climate advocacy, < 1˚C and < 350 ppm seem to have dropped by the wayside.

- **1.5˚C is not a safe limit**

Many lines of evidence show that climate systems have/will have passed their tipping points at 1.5˚C, and that tipping points are now in play, including at both poles. Coral reef systems have been in a death spiral for more than a decade. Permafrost, boreal forests and the Amazon are becoming net carbon emitters.

In September 2022, Stockholm University's David Armstrong McKay and his colleagues concluded that even global warming of 1˚C risks triggering some tipping points.[19] At 1.5˚C, "we're at risk of crossing irreversible thresholds on unique and threatened systems", says Johan Rockström, director of the Potsdam Institute for Climate Impact Research.[20]

This year, new research has reaffirmed that 1.5˚C is too high to prevent tipping points and that there is a "significant" risk of large Amazon forest dieback if global warming overshoots 1.5˚C.[21] As well, another new paper warns that "1.5˚C is too high for polar ice sheets" and the Paris Agreement target won't protect them.[22]

As well, Earth may have hit a point of irreversible moisture loss in its soil.[23] And the natural sequestration of CO_2 by the terrestrial biosphere peaked in 2008 and is in decline, accelerating climate change.[24]

At a May 2008 climate conference at the Academy of Science conference in Canberra, the international guest speaker was Dr Neil Hamilton, then head of the WWF Arctic Programme. He told a somewhat stunned audience that the WWF was not trying to preserve the Arctic ecosystem

[17] independent.co.uk/climate-change/opinion/arctic-ocean-ice-temperature-climate-change-b1790779.html
[18] nature.com/articles/461472a
[19] science.org/doi/10.1126/science.abn7950
[20] phys.org/news/2022-06-irreversible-shifts-climate-experts.html
[21] carbonbrief.org/significant-risk-of-amazon-forest-dieback-if-global-warming-overshoots-1-5c/
[22] nature.com/articles/s43247-025-02299-w
[23] abc.net.au/news/science/2025-03-28/earths-big-dry-out-freshwater-loss-irreversible-climate-change/105100272
[24] rmets.onlinelibrary.wiley.com/doi/10.1002/wea.7668

because "it was no longer possible to do so". That is, it had already passed its tipping point, at a time when global average warming was 0.8°C!

Likewise the world's greatest coral researcher, Australia's Charlie Veron, told the Royal Society in London in 2009 that a safe boundary for reef systems was 0.5°C.[25]

The evidence grows that the 1.5°C target was never a safe target for humanity.

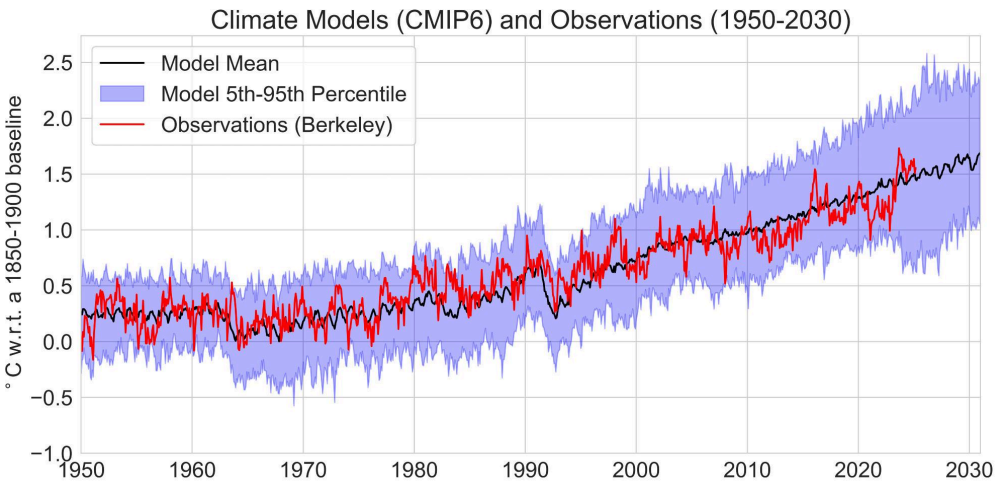

Figure 2: Climate models (CMIP6) and observations (ClimateBrink).

- **We are already at 1.5°C.**

In 2018, the IPCC mid-range projected year for the world to warm to 1.5°C above pre-industrial levels was 2040.[26] But a new World Meteorological Organization report this year indicates that Earth will cross this point in just two years, with a "70% chance that the 2025-2029 five-year mean will exceed 1.5°C above the 1850-1900 average".[27]

In fact, 2023 was 1.5°C and 2024 reached 1.6°C,[28] and the running average for the last 24 months has been close to 1.6°C. A new paper (currently in pre-print) shows that for one temperature data set, the warming trend reached 1.5°C in 2024, and four other data sets show 2026.[29]

For all practical purposes, the warming trend has hit 1.5°C, as James Hansen has noted: "Averaged over the El Nino/La Nina cycle, the 1.5°C limit has been reached".[30] This is also consistent with the CMIP6 model projections (Figure 2, produced by Zeke Hausfather).[31]

- **1.5°C is not a point of system stability**

Scientists say it is a big mistake to think we can "park" the Earth System at any given temperature rise – say 2°C – and expect it to stay there.[32] The late Prof. Will Steffen and his coauthors in their widely-read 2018 "Hothouse Earth" paper warned that "even if the Paris Accord target of a 1.5°C to 2°C

[25] youtube.com/watch?v=xHo4vb-lPDQ
[26] ipcc.ch/sr15/graphics/https://www.ipcc.ch/sr15/graphics
[27] wmo.int/sites/default/files/2025-05/WMO_GADCU_2025-2029_Final.pdf
[28] climate.copernicus.eu/global-climate-highlights-2024
[29] assets-eu.researchsquare.com/files/rs-6079807/v1_covered_209e5182-d9a5-4305-a4e0-70204151d2b3.pdf
[30] mailchi.mp/caa/global-warming-has-accelerated-why-what-are-the-consequences?e=3763203384
[31] instagram.com/p/DKCkGRYOqtT/
[32] theguardian.com/environment/planet-oz/2018/oct/06/earths-climate-monsters-could-be-unleashed-as-temperatures-rise

rise in temperature is met, we cannot exclude the risk that a cascade of feedbacks could push the Earth System irreversibly onto a 'Hothouse Earth' pathway".[33]

In other words, by 1.5˚C, there may be so many carbon-cycle and other feedbacks under way, and active system instabilities, that the climate will not stabilize at 1.5˚C, but rather it will move towards a new point of equilibrium at a significantly higher temperature. The implication is that our choice is either to cool the planet back to Holocene (pre-industrial) conditions, or accept that the next point of system stability may be around 3˚C.

This is a point that paleoclimatologists make repeatedly, that the climate's history over the last 800,000 years shows temperature and CO_2 oscillating between two levels, interrupted by abrupt instability, offering critical insights into today's rapidly changing climate. The climate see-sawed between glacials around 180 ppm which were 3-5˚C cooler than recent centuries, and the warmer interglacials around 280 ppm (see figure 3). We are now approaching 430 ppm.

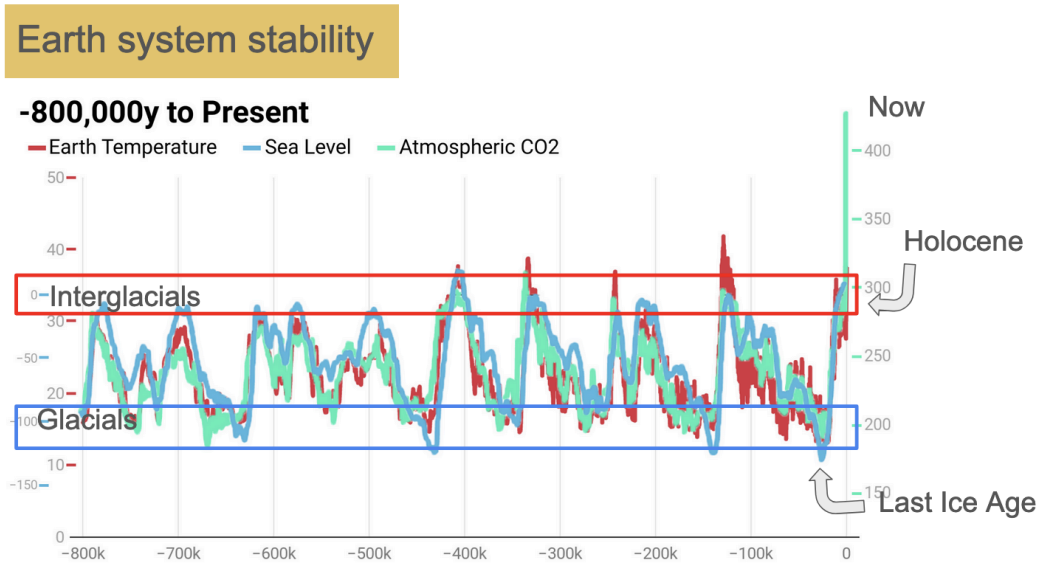

Figure 3: Earth system stability

Hansen says we have now left a state of system stability — the Holocene — and are headed into a period of rapid, unstable (non-linear) change driven by record-fast increases in CO_2 and amplifying and cascading feedbacks. The current 1.5˚C climate is not a point of system stability. That point lies at a significantly higher warming when the current system feedbacks have played themselves out to equilibrium. The last time CO_2 was around the current level — 3 to 3.3 million years ago — temperatures were around 3˚C hotter than pre-industrial and sea levels 25 metres higher.[34]

In other words, 1.5˚C is not a destination, but a signpost on a dusty road to somewhere hotter. So it cannot be an advocacy endpoint either, from a "science-based" perspective.

[33] pnas.org/content/115/33/8252
[34] pnas.org/doi/10.1073/pnas.1809600115

Part 4. Advocacy assumptions

There are implicit and explicit assumptions behind the common advocacy position: on overshoot and on the efficacy of emissions reductions. These need some exploration.

- **Overshoot and the return to 1.5˚C by 2100**

Overshoot means exceeding a temperature goal, whilst over time reducing emissions to zero and large-scale carbon drawdown can result in a reduction in the level of greenhouse gases so the temperature drops back to the desired goal. This scenario has been widely adopted by advocates, with the goal of "overshoot and the return to 1.5˚C by 2100". With warming already at the 1.5˚C level, this scenario envisages overshoot for up to three-quarters of a century. Now, overshoot of 1.5˚C is inevitable, but for how long is it desirable? Answer: as short as possible. And are there methods to shorten the length of overshoot? Answer: yes, see Part 5 below.

In 2024, researchers again warned of "overconfidence in climate overshoot", that is, exceeding a temperature target for decades, on the assumption that negative emissions technology will be able to later reduce the heating and restore conditions as if there had been no overshoot. Extinctions caused by overshoot are one thing that can't be restored: once a species is extinct, lowering the temperature won't bring it back. The researchers show that:

> "Global and regional climate change and associated risks after an overshoot are different from a world that avoids it… the possibility that global warming could be reversed many decades into the future might be of limited relevance for adaptation planning today [because] temperature reversal could be undercut by strong Earth-system feedbacks resulting in high near-term and continuous long-term warming… Only rapid near-term emission reductions are effective in reducing climate risks."[35]

- **Emissions reductions will reduce the rate of warming in the near term**

The advocacy emphasis on emissions reduction rests on the assumption, as best I can tell, that such reductions will bend down the temperature curve in the near term up to 2050, because "every fraction of a degree (above 1.5˚C) matters". But is this the case?

A by-product of burning fossil fuels is sulphate aerosols, which have a strong cooling impact of 0.5 to 1˚C (and possibly more) and have been temporarily "masking" some warming. There is uncertainty about the size of the aerosol forcing (due to the lack of suitable satellite instruments), and it is not well incorporated into climate models. Researchers say that without aerosols, "the global warming we see today would be 30–50% greater" and that over the next 20 to 30 years their disappearance may add "as much as 0.5˚C to global warming" as their production decreases.[36]

Aerosols are short-lived in the atmosphere, and are removed from the atmosphere as acid rain, which has far-reaching adverse effects on human communities and ecosystems. So there are good reasons to reduce aerosol production by "cleaning up" emissions, that is, reducing the use of high-sulphur fuels such as coal and shipping fuels. This has been done at scale in China, and by the World Maritime Organisation mandating cleaner fuel policies, for example. But doing so has revealed what Hansen described as our "Faustian bargain".[37]

The declining use of high-sulphur coal and oil due to clean air policies has reduced the aerosol impact and hence the temporary cooling effect which has been shielding us from some warming.

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[35] nature.com/articles/s41586-024-08020-9
[36] nature.com/articles/d41586-022-03763-9
[37] nytimes.com/2023/08/30/opinion/columnists/the-faustian-bargain-of-reducing-air-pollution.html

The short-term impact is an acceleration in the rate of warming. This is precisely what has been observed over the North Atlantic which is the world's busiest shipping zone and where sea-surface temperatures in recent years have increased several standard deviations beyond model forecasts. A preprint of new research shows that China's aerosol cleanup is likely a key contributor to recent global warming acceleration, and to Pacific warming trends, sufficient to explain a majority of the rise in the global warming rate since 2010.[38] The decrease in aerosols is also likely to have contributed to the recent reductions in low-cloud cover in the northern mid-latitudes and tropics, which is one cause of the accelerated rate of warming.[39] And a 2024 research paper concluded that recent reductions in aerosol emissions have increased Earth's Energy Imbalance.[40]

The continued application of clean air policies, and a broader reduction in the use of fossil fuels would mean that the aerosol-shielding impact will further diminish and continue to contribute to a higher rate of warming. For example, modelling shows that a 5% annual reduction in emissions of any single greenhouse gas, from 2020 and based on a middle-road emissions path, has no statistically significant effect on warming for more than two decades, as compared to a no-mitigation pathway.[41]

Rapid reduction in fossil fuel emissions is the key climate mitigation action, but the aerosol Faustian bargain casts doubt as to how much that will ameliorate warming over the next two or three decades.

- **The era of climate triage?**

If climate advocacy centers almost exclusively on 1.5˚C — without serious discussion of the safe thresholds like sub-1˚C warming — then that advocacy implicitly accepts 1.5˚C as the best we can do.

If this is the case, that means that a whole lot of physical and ecosystems will be wiped out or be transformed to discretely different, unrecognisable or dead states: the Arctic, Amazon and Himalayas, polar glaciers and Boreal forests, drowned river deltas and low-lying islands, desertifying dry subtropical zones, the Sahara crossing the Mediterranean, and so on. This climate triage is in effect like a bad night in the emergency department, saving some cases, while surrounded by death and destruction. This is a long way from the "protecting the places we love" campaigns of not-so-long ago.

Prof. Hans Joachim Schellnhuber, Director Emeritus of the Potsdam Institute and perhaps the leading figure in European climate science and politics, reminded us in 2009 that "in the long run, there is the problem of sea level rise. *One degree, in the long run, translates into 15-20 meters sea level rise in equilibrium*. Two degrees, the target of the European Union, means sea level rise of 30-40 meters – over maybe a thousand years. Draw a line around your coast – probably not a lot would be left (emphasis added)."[42] Is this what we are settling for?

So why has 1.5˚C become the dominant target? Is it because it sits within the current (delusional) policy-making paradigm? Before 2015, when 2˚C was the focus of policy-making, many NGOs pushed for a lower figure because they knew 2˚C wasn't safe. So now, when the evidence is overwhelming that 1.5˚C is not safe, why not work to again open the Overton Window?

Many questions could be asked. What does leadership look like in this era where we are heading for civilisational collapse? How does 1.5˚C match with the view that advocacy "must be based on climate

[38] researchsquare.com/article/rs-6005409/v1
[39] science.org/stoken/author-tokens/ST-2289
[40] nature.com/articles/s43247-024-01324-8
[41] nature.com/articles/s41467-020-17001-1
[42] uniavisen.dk/en/russian-roulette-odds-if-were-lucky

justice and science"? Do advocates agree — as they used to say and campaign for — that less than 350 ppm is a safe operating space for humanity, as scientists assert?[43] If so, why not say it?

Is it because that may take one outside the hyper-pragmatic political boundary of the COP circus run by petrostates, where 29 years of conferences have resulted in CO_2 levels and temperatures rising today at record rates? If that is the case, some cool air outside the ball-room might be a good thing.

Too often, climate strategy has been reduced, if somewhat unconsciously, to a "triage politics" of selecting what to save and what to abandon. Whilst advocates would likely claim this is grossly unfair, that is what setting 1.5˚C as the goal means.

In the absence of normative goals for the maximum protection of species, peoples and the Earth system, there is a tendency for political trade-offs between protection and sounding politically reasonable. Thus goals may be set, only to be abandoned as warming accelerates. "Avoiding dangerous climate change" has already been left by the wayside. So, apparently, has 350 ppm. So what's the strategic purpose now?

Part 5. An alternative scenario: climate interventions

For more than a decade, Breakthrough has argued that avoiding dangerous disruption to the climate system — that is, ensuring a safe and stable climate for humanity and nature — requires maintaining the relatively stable conditions of the Holocene epoch over the past 9,000 years up to 1900, during which global temperatures fluctuated within a narrow 0.5˚C range. As Schellnhuber states:

> "Only a return to pre-industrial levels of CO_2 would be enough to guarantee a safe future for the planet… even a small increase in temperature could trigger one of several climatic tipping points, such as methane released from melting permafrost, and bring much more severe global warming. It is a very sweeping argument, but nobody can say for sure that 330 ppm is safe… Perhaps it will not matter whether we have 270 ppm or 320 ppm, but operating well outside the [historic] realm of carbon dioxide concentrations is risky as long as we have not fully understood the relevant feedback mechanisms.'"[44]

In 2022, a group of Australian scientists suggested that from a geologic perspective "a justifiable aim for a future climate is one akin to pre-industrial conditions".[45] Other evidence points to the need to return to pre-industrial levels of 280 ppm, for example in relation to the polar regions.[46]

Is it possible to achieve such an outcome, and avoid a large and lengthy overshoot? If this were the goal, advocates and policy-makers would adopt a "three levers" approach to reversing global warming. This is what the Climate Crisis Advisory Group in 2021 termed a "reduction, removal and repair strategy":[47]

- **Lever 1.** Reduce emissions to zero at emergency speed. 2035 — not 2050 — is the crucial time frame. The primary task is to build capacity for emergency speed and scale emissions elimination, and to minimise the rate and magnitude of warming. Long-term targets are an excuse for procrastination, as the history of international climate policy-making shows. Fast reduction of methane emissions must be a focus, because the gas is short-lived in the

[43] nature.com/articles/461472a
[44] regione.vda.it/energia/rassegna_stampa/allegati/allegato589ita.pdf
[45] nature.com/articles/s41558-022-01446-x
[46] iccinet.org/wp-content/uploads/2015/11/ICCI_thresholds_v5_151128_high_res1.pdf
[47] ccag.earth/reports/the-global-climate-crisis-and-the-action-required

atmosphere and its mitigation can reduce the climate forcing (the energy imbalance driving warming).

- **Lever 2.** Remove carbon from the atmosphere. Removing CO_2 from the atmosphere can cool an overheated Earth. Stabilisation (at current climate) would require carbon drawdown of 70 ppm (back to ~350 ppm) to stop further warming. Lowering the current level of warming would require more drawdown.[48] This in itself is a massive task that requires a global, coordinated effort. Drawdown at scale is essential, but it is a slow process that will not provide active cooling until it is greater than the level of ongoing emissions. Some nature-based processes are well-known, safe and can be enhanced. Other new technologies are far from being proven viable, safe and scalable, so large-scale research and deployment is crucial.
- **Lever 3.** Short-term global cooling and repair. We need to urgently investigate the potential of safe ways to cool the planet and/or protect vital climate systems in the near term, particularly in the polar regions, till the other two levers have had time to take effect. Options for polar cooling include enhancing the capacity of marine clouds to reflect incoming radiation, and sulphate aerosols injection (SAI) — using cooling aerosols — which can have a strong, immediate cooling effect. Early studies of climate repair should be incrementally scalable – so they can be paused or reversed at any point; and transparency and good governance will consolidate trust in the process, says the Climate Crisis Advisory Group.[49]

This three-lever strategy is illustrated in Figure 4. The harsh reality is that the first two levers alone — zero emissions and drawdown — are not sufficient to prevent a catastrophe of difficult-to-comprehend proportions. Warming to date plus the observed Earth's Energy Imbalance adds up to well more than 2˚C for today's level of greenhouse gases.

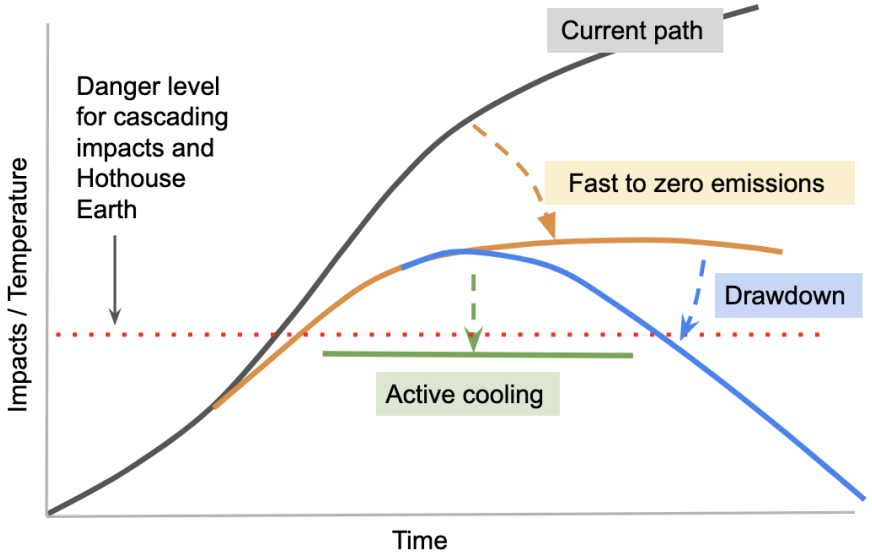

Figure 4: The three-lever strategy

And, as discussed, the paleoclimate record suggests the current level of CO_2 would result in 3˚C or more of warming in the longer term, so a strategy of only emissions elimination will not prevent a global disaster. Large-scale carbon drawdown is essential, but this cannot be done at a scale and speed fast enough to prevent both warming activating more tipping points and the possibility of a cascade of consequences or triggering of the "Hothouse Earth" scenario.

[48] essd.copernicus.org/articles/12/2013/2020
[49] ccag.earth/reports/a-critical-pathway-for-a-manageable-future-for-humanity.

Hence the third lever of action is required: the urgent scaling up of research and investigation into an additional range of climate interventions that aims to rapidly cool the planet, including various albedo modification/solar radiation management (SRM) options that will alter the Earth system's reflectivity.. If shown to be efficacious, SRM could play a vital role in flattening the warming peak whilst allowing time for zero emissions and carbon drawdown to create a path back to a safe, liveable climate.

Proposed albedo modification methods include:

- Marine cloud brightening (MCB) to increase reflectivity, whereby saltwater spray is added to the lower atmosphere which has a high water vapour content, making existing clouds whiter (more reflective) or helping new clouds to form in a clear sky. Field research on MCB to protect the Great Barrier Reef is under way.[50]
- Enhancing surface reflection with mirrors, such as the Mirrors for Earth's Energy Rebalancing (MEER) project which is at an early stage of research development, but appears to not be limited by material or energy use constraints. [51]
- Increasing reflection of the terrestrial surface, including everything from ice whitening to more reflective human infrastructure such as roofs.
- Decreasing the amount of high-altitude cirrus clouds to allow more out-going radiation.
- Space-based methods, which are highly speculative.

Most work is going into stratospheric aerosol injection (SAI), which increases the amount of stratospheric aerosols in order to reduce incoming solar radiation. This in a way mimics the cooling effect of major volcanic eruptions that inject sulphur dioxide gas into the stratosphere creating small particles of sulphuric acid that reflect some sunlight back to space. When Mount Pinatubo in the Philippines exploded in volcanic eruption in 1991, it cooled the planet by 0.6˚C for about 15 months due to the particulate matter released.

There is strong evidence that SAI, if applied at a scale, could significantly reduce or fully eliminate the earth's overheating in a relatively short period of time. SAI is the most studied form of albedo modification, with hundreds of published research papers pointing to sizable benefits, but with potentially significant risks.

Unlike carbon drawdown (CDR), albedo modification does not aim to reverse warming by reducing the CO_2 level, nor does it have a direct effect on ocean acidification caused by rising levels of CO_2. However, as an interim measure, it could "reduce some harm done by climate change during the time it takes for societies to implement deep cuts in greenhouse gas emissions while also potentially developing and deploying CDR systems. It could also, in theory, cool the climate quickly and thus prove highly valuable should society at some point face rapid changes in climate that cause unacceptable damage."[52]

Research on albedo modification and especially SAI is expanding rapidly. So are the number of NGOs focused on research, funding, advocacy and governance, including Operaatio Arktis, Arctic Circle, The Degrees Initiative, Silver Lining, Climate Crisis Advisory Group, Climate Overshoot Commission, MEER, SRM 360, Geoengineering Research Governance Project, Carnegie Climate Governance Initiative, and the Australian Forum for Climate Intervention Governance, to name but a few.

[50] nature.com/articles/d41586-021-02290-3
[51] meer.org
[52] agu.org/Share-and-Advocate/Share/Policymakers/Position-Statements/Climate-Intervention-Requirements

Since SAI has become highly politicised, how should its efficacy be assessed? The central question is whether SAI is of net social and environmental benefit. Some people object that it is "interfering with nature". Whilst a nature conservation approach invokes a "hands off nature" response to proposed climate interventions, the reality is that "hands off" will no longer protect nature.

A second line of opposition is that it may do damage to particular systems, regions and vulnerable people, compared to the status quo. But that is not the real-life choice. That choice is the impacts of SAI versus the impacts in a significantly hotter world without SAI.

Unfortunately there is no ideal path away from climate disruption, so every tool at our disposal must be explored, and there needs to be an evidenced-based assessment of what is the least-worst option to protect what is at great risk.

Last year, Gwynne Dyer reported that: "Almost nobody in the climate science community really believes anymore that we can stop the warming at a place that is relatively safe without direct human intervention of some sort in the climate system."[53] And a landmark 2024 study showed the Global South is more supportive of SRM interventions.[54] In 2021, the prestigious journal *Nature* ran an editorial titled: "Give research into solar geoengineering a chance".[55]

Delaying a high-level global mission on climate interventions is dangerous. Michael MacCracken, chief scientist for climate change programs with the Climate Institute in Washington DC, provides a compelling case for prioritising intervention without delay, identifying the most urgent case as the potential for moderating amplified Arctic warming.[56]

He says that to date, there has been no high-level interest among international decision-makers in organizing a mission-focused climate intervention research and deployment program aimed at preventing temperature increases exceeding the 1.5–2˚C Paris band. Instead, intervention "seems to be viewed as a potential emergency response that could be resorted to some decades in the future as a possible remedy after substantial impacts are widely evident and the consequences are becoming unacceptable".

But time is not on our side. MacCracken says that insufficient attention is being given to the inability of a delayed intervention to reverse disruptions of the landscape, undo the irreversible losses of biodiversity, or substantially slow the accelerating pace of sea level rise from the loss of ice sheets. Delay research too long and interventions may no longer work as well or at all: "Putting off initiation of actual climate intervention until there is much greater understanding might well lead to a situation where the transient conditions associated with restoring the past's milder conditions might themselves be unacceptably disruptive."

MacCracken also notes that many of the ethical analyses have been primarily focused on evaluating the relative risks and benefits of climate intervention on its own rather than as compared to the risks of projected changes without climate intervention. The relevant question is not what would be the risks of SRM or other interventions compared to the current climate, but the costs and benefits compared to a climate 2–4˚C hotter.

In a recent interview, MacCracken discusses how climate interventions are necessary to ensure the ongoing plausibility of achieving the UN Sustainable Development Goals.[57] He also suggests that the UN structures for sustainable development could be the overseeing climate interventions

[53] thewalrus.ca/seven-truths-climate-crisis/
[54] peteirvine.substack.com/p/landmark-study-shows-the-global-south
[55] nature.com/articles/d41586-021-01243-0
[56] agupubs.onlinelibrary.wiley.com/doi/10.1002/2016EF000450
[57] genn.cc/mike-maccracken/

governance mechanism, given that the low-latitude nations are the most vulnerable and it was mainly the developed nations that put them in this predicament.

A lack of governance has not been a hindrance to research. State actors including the UK, the European Union, Russia, China, India, the USA and Australia have or are funding albedo modification research including SAI and cloud brightening, and funds are now also being made available by the Degrees Initiative to developing nations so they can better understand the issue. China, for example, has a weather modification program that already employs an estimated 35,000 people, and in 2020 announced plans that would increase fivefold the world's biggest cloud-seeding operation. And it is a leading nation in climate intervention research.

In the UK, the government is supporting small-scale climate intervention experiments as part of a £50m government-funded programme, through the Advanced Research and Invention Agency (Aria), to provide "critical" data needed to assess the potential of the technology.[58]

As circumstances become more desperate, and in the absence of agreed upon global governance, affected states may simply take unilateral action. Kim Stanley Robinson's prophetic 2020 cli-fi book, *The Ministry for the Future*, starts with a mega-heatwave in India that kills thousands in the state of Uttar Pradesh, and then tells of the global consequences. In such circumstances, asks Robinson, can others have an objection to such an impacted state taking unilateral action:

> "Throwing dust up into the atmosphere would be, I think, an emergency gesture on a temporary basis, in effect imitating a volcanic eruption and hoping that five years of slightly lower temperatures would save us from brutal heat waves. And if one nation suffers a catastrophic heat-death event and then decides to go this route, no other nation will have any legal or moral standing to object to it. Nor is it clear that it would be bad for civilization or the biosphere. Arguments about moral hazard become irrelevant in such an emergency, and worries about secondary effects are speculative and not supported by what has actually happened after real volcanic explosions."[59]

The choice for climate advocates is whether they will advocate for an international, mission-focused climate intervention research and testing program, or watch it happen from the sidelines.

Part 6: Conclusion

Despite 35 years of intense negotiations, climate-warming emissions have not been reduced, and many impacts have occurred faster than forecast and beyond model projections. Humanity is now in extremely dangerous climatic territory that is way beyond previous human experience, and at a time when climate denial-and-delay strategies amongst nations and institutions is resurgent. .

Do we have the capacity and leadership to recognise this existential threat to our survival generated by current policies, and drive change at emergency speed?

There is no silver bullet in climate advocacy. A diverse range of "reduce, remove, repair" actions are necessary to seek maximum protection for all people and species, by preventing a cascade of events leading to a "Hothouse Earth", reversing global warming and returning to safe climate conditions.

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[58] theguardian.com/environment/2025/apr/22/uk-scientists-outdoor-geoengineering-experiments
[59] nytimes.com/2021/06/22/magazine/ezra-klein-climate-crisis.html

This is a complex and unfamiliar objective, with many potential risks and a large number of difficult scientific, technical, social and ethical questions. It is a matter of weighing benefits and costs, and of managing existential risks. Some questions advocates may consider include:

- Can a safe climate be achieved, in the next 100 years, if climate actions involve only the elimination of greenhouse gas emissions?
- Are unacceptable, dangerous near-term climate impacts likely in the absence of climate interventions?
- What measures and technologies could be safely deployed to return critical elements of the climate system to a viable and stable state? And under what circumstances would these need to be deployed?
- Are proposed climate interventions feasible in terms of their material and energy inputs?
- Will delay in researching and deploying climate interventions degrade their usefulness?
- Which authorities would need to allow the deployment of these measures, and what are, amongst others, the legal, economic, political and ethical implications of doing so?
- And finally, what are the risks in a world with albedo modification, and without (by relying on decarbonisation only)?

Concerns about the risks of solar radiation management (SRM) are valid, but they must be weighed in context. The critical question is not whether SRM has downsides, but how those compare to the consequences of warming unmitigated by SRM. If SRM could halve warming — for example, from 2˚C to 1˚C — what would the overall risk–benefit balance look like?

If the world reaches 2.5–3˚C of warming, it will be too late to regret not having seriously considered a full range of climate strategies while they still had a chance to make a difference. Every moment we delay answering these vital questions is a step closer to new catastrophes, and a further step away from achieving a safe climate.