BREAKTHROUGH
National Centre For Climate Restoration

BRIEFING NOTE

# Accelerating climate disruption and the strategy to reduce, remove and repair

AUGUST 2023


## Summary

- Climate risks are cascading, non-linear and underestimated. Tipping points are happening faster than forecast; some have already occurred at less than the current 1.2˚C of warming.
- To provide maximum protection for the places and peoples we care about requires returning to a climate similar to the relatively stable Holocene conditions of the last 9000 years when carbon dioxide ($CO_2$) levels did not exceed 280 parts per million prior to 1900.
- A "three levers" approach — "reduce, remove and repair" is required:
  - Reducing emissions to zero at emergency speed;
  - Removing carbon by drawdown to return atmospheric conditions to the Holocene zone; and
  - Urgent research to identify safe interventions that protect and repair vital systems and, in the shorter term, aim to prevent warming reaching a level that triggers a cascade of calamitous tipping points that are irreversible on human timescales.
- The harsh reality is that the first two levers alone — zero emissions and drawdown — are not sufficient to stop the Earth system charging passing 1.5˚C within the next decade (nor 2˚C in all likelihood), regardless of the emissions path.
- Even as the world moves to zero emissions, and $CO_2$ levels start to decrease by natural processes and by $CO_2$ removal, albedo modification for a limited period can flatten the level of peak warming — and perhaps help avoid existential climate impacts and extreme damage — until the other processes fully kick in.



Published by Breakthrough - National Centre for Climate Restoration
Melbourne, Australia
breakthroughonline.org.au
info@breakthroughonline.org.au

## The new climate crisis and the strategy to reduce, remove and repair

The current wave of record-smashing climate extremes is shocking. But it should not have been unexpected. Earlier this year the Breakthrough discussion paper *Faster, higher, hotter* noted:

> "System-level change and tipping points are happening faster than forecast, with a number of crucial climate system elements already passed tipping at the current 1.2°C of warming. Risks are cascading, non-linear and underestimated; prudent risk management requires consideration of the bad-to-worst-case-scenarios."[1]

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,[2] just one data point in an alarming mountain of research on tipping points presented in the last year and a half. Clearly, even the current level of warming of around 1.2°C is unacceptably dangerous.

To protect small-island states, the Great Barrier Reef, Antarctica, Greenland, the Amazon — indeed to provide protection for the many places and peoples we care about — requires returning to a climate similar to the relatively stable Holocene conditions of the last 9000 years and fixed human settlement, during which time $CO_2$ levels did not exceed 280 parts per million (ppm). It also requires preventing a cascade of tipping points in the meanwhile.

For example, 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".[3] Other evidence points to the need to return to pre-industrial levels of 280 ppm, for example in relation to the polar regions.[4]

If this were the goal, activists and policymakers would advocate a "three levers" approach to reversing global warming: a strategy to rapidly "reduce, remove and repair".[5] That means:

1. Reducing emissions to zero at emergency speed;
2. Removing carbon by drawdown (in addition to natural processes) to return atmospheric conditions to the Holocene zone; and
3. The urgent research to identify safe interventions that protect and repair vital systems and, in the shorter term, aim to prevent warming reaching a level that triggers a cascade of calamitous tipping points that are irreversible on human timescales.

## Emissions reduction is not enough

The harsh reality is that first two levers by themselves — zero emissions and drawdown — are not sufficient to stop the Earth system charging past 1.5°C within the next decade, regardless of the emissions path,[6] and to significantly higher temperatures — likely more than 2°C around mid-century — with truly catastrophic impacts for some peoples, regions and natural systems. In essence:

- Warming to date plus the observed Earth Energy Imbalance (EEI) at the top of the atmosphere adds up to more than 2°C for today's level of greenhouse gases. EEI is rising at an alarming rate which suggests the amount of warming in the pipeline is increasing.[7] And the paleoclimate

[1] breakthroughonline.org.au/papers
[2] science.org/doi/10.1126/science.abn7950
[3] nature.com/articles/s41558-022-01446-x
[4] iccinet.org/wp-content/uploads/2015/11/ICCI_thresholds_v5_151128_high_res1.pdf
[5] static1.squarespace.com/static/60ccae658553d102459d11ed/t/60d421c67f1dc67d682d8d29/1624515027604/CCAG+Launch+Paper.pdf
[6] See for example, Table SPM.1, ipcc.ch/report/ar6/wg1/chapter/summary-for-policymakers
[7] twitter.com/LeonSimons8/status/1522342203481370625

record suggests the current level of $CO_2$ is sufficient for 3˚C or more of warming in the longer term.[8] Thus a strategy of emissions elimination only will not prevent catastrophic outcomes.

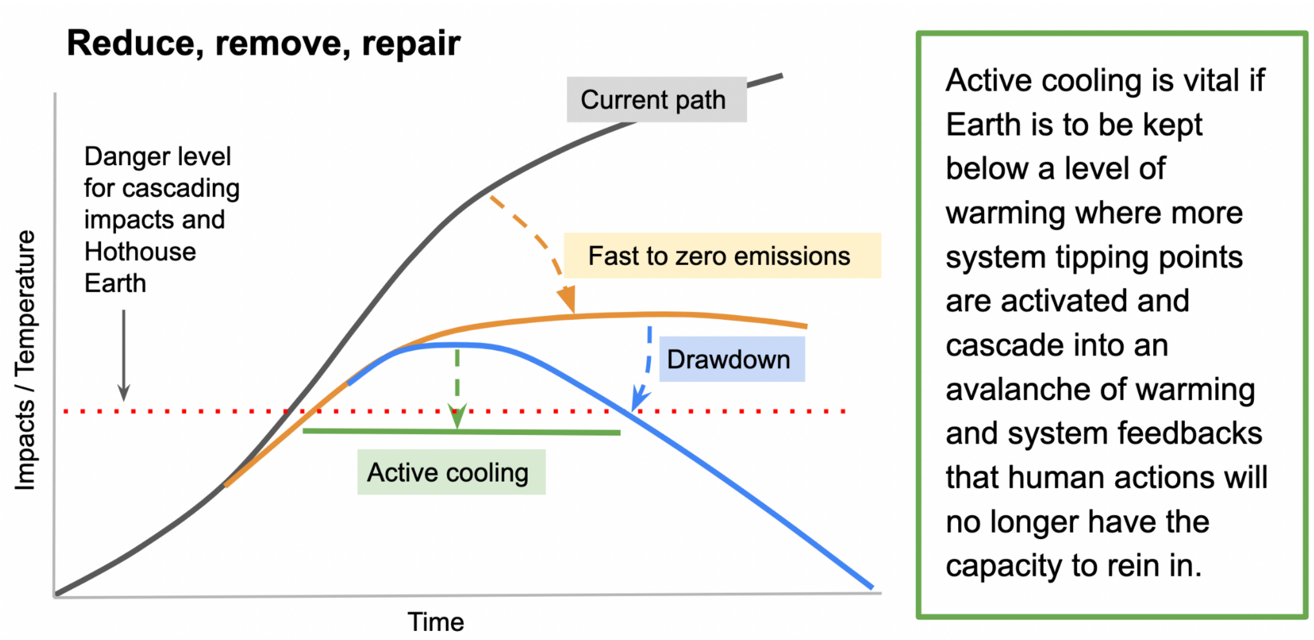
- A safe-level of greenhouse gases to preserve and restore vital climate systems likely requires returning to the pre-industrial $CO_2$ level of around 280 ppm. On top of a zero-emissions regime, large-scale carbon drawdown is essential in achieving this goal, but this cannot be done at a scale and speed fast enough to prevent more tipping points being activated in the near term and the possibility of a cascade of consequences leading to enhanced warming.

- Thus a '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 is required by changing the Earth system's reflectivity, known as albedo management. This includes solar radiation management (SRM) cooling which, if shown to be efficacious, could play a vital role in flattening the warming peak whilst allowing time to achieve zero emissions and carbon drawdown on a path back to a safe, liveable climate.[9]

There is a near-term risk that warming may also trigger the "Hothouse Earth" scenario, in which climate system feedbacks and their mutual interaction drive the Earth System climate to a "point of no return", whereby further warming would become self-sustaining (that is, without further human-caused perturbations). Scientists have warned that this is possible even in the 1.5–2˚C range.[10]

Even 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.[11]

As illustrated,[12] as the world moves to zero emissions, and $CO_2$ levels start to decrease by natural processes and by carbon dioxide removal (or drawdown), albedo modification can flatten the level of peak warming — and perhaps help avoid existential climate impacts and extreme damage — until the other processes fully kick in.




[8] pnas.org/doi/10.1073/pnas.1809600115
[9] annualreviews.org/doi/abs/10.1146/annurev-earth-042711-105548
[10] pnas.org/doi/10.1073/pnas.1810141115
[11] phys.org/news/2022-06-irreversible-shifts-climate-experts.html
[12] Adapted from royalsocietypublishing.org/doi/10.1098/rsta.2016.0454

Climate intervention is the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change".[13] Climate interventions, also termed geoengineering, climate restoration and climate repair, fall into two broad categories: $CO_2$ removal and albedo modification.

## Carbon dioxide removal

Carbon dioxide removal (CDR) involves taking the excess $CO_2$ out of the atmosphere and the ocean, and storing it safely and securely in biomass, soils or rock formations, or in neutralised or stable forms in the oceans. CDR techniques may be classified as nature-based solutions and technical solutions, and include:

**Nature-based solutions**

- Ecosystem sequestration, in which ecosystems can be restored or created to use photosynthesis to capture $CO_2$ and store it in biomass, for example in peatlands, terrestrial forests and shallow saltwater ecosystems such as mangroves, kelp and seagrass. Reforestation and wetlands restoration is well-established, safe and the most cost-efficient CDR option at present.
- Regenerative land management practices that enhance water retention and soil carbon, which are proven and cost effective, including the use of biochar to store carbon and rejuvenate soils.
- Marine up-welling, which extends the scale of marine kelp, sea grasses and seaweed farms, offering new carbon sinks, plus production of food for cattle which increases milk yields whilst lowering methane emissions from livestock. Biomass allowed to drift down to the deep ocean would remain for hundreds of years or millenia.
- Ocean iron fertilisation, in which fertilising deep ocean areas with light sprinklings of iron dust can generate, in a matter of months, green, plankton-rich forests, accompanied by burgeoning fish stocks and a huge variety of marine wildlife. One result is more organic matter settling in the deep ocean.
- Enhanced mineralisation, mimicking a process in nature where silicate rock weathering on land binds $CO_2$. Crushed carbonate rock can also be exposed to $CO_2$ dissolved in water to create bicarbonate ions that can be stored in the ocean. This has been demonstrated in the laboratory and in small scale field trials, but has yet to be demonstrated at scale.

**Technical solutions**

- Negative emissions construction, the increased use of plantation timber (and potentially new forms of concrete and road materials) to store carbon in the built environment.
- Ocean alkalinization, the adding of alkaline substances — minerals such as olivine, or artificial substances such as lime or some industrial byproducts — to seawater to enhance the ocean's natural carbon sink by converting dissolved $CO_2$ into stable bicarbonate and carbonate molecules. This idea is at an early stage of development.
- Direct chemical capture by machines, to store in geological formations or in immobile form in the ocean or ocean sediments, which is now at the demonstration stage, but cost and energy use are currently prohibitive.
- Bioenergy with carbon capture and storage (BECCS), the use of crops to manufacture bioenergy, with underground storage of $CO_2$. This technology is unproven at scale or cost, but a favourite of policymakers and incorporated into Integrated Assessment Models and the Paris Agreement as a

[13] royalsociety.org/topics-policy/publications/2009/geoengineering-climate

means of justifying a longer life for the fossil fuel industry via bioenergy with carbon capture and storage (BECCS) “offsets” for continuing carbon pollution.

Some of these techniques have well-known safety profiles and are at a high technical readiness level, whilst others are unproven at scale and cost, or speculative, and need technological development, safety testing and suitability evaluation.

## What scientists say

**Prof. JAMES HANSEN**
“We will need to return to a global climate no warmer than the middle of the 20th century, and likely somewhat cooler, for the sake of maintaining global shorelines.“[14]

**Prof. JOHAN ROCKSTRÖM**
"I just get tired...Tired of hearing that 1.5˚C is a "target" or "goal". IT IS NOT. It is a limit. The only real goal is 0˚C. And not bad 1.5˚C, when we LIKELY tip GIS, WAIS, Tropical Coral Reefs and Abrupt Boreal Permafrost, and get more floods, droughts, heat, disease, storms."[15]

**Prof. WILL STEFFEN**
“It is clear from observations of climate change-related impacts in Australia alone—the massive bushfires of the 2019-2020 Black Summer, the third mass bleaching of the Great Barrier Reef in only five years, and long-term cool-season drying of the country's southeast agricultural zone—that even a 1.1˚C temperature rise has put us into a dangerous level of climate change."[16]

**Prof. HANS JOACHIM SCHELLNHUBER**
"Our survival would very much depend on how well we were able to draw down CO2 to 280 parts per million."[17]

**Prof. NERILIE ABRAM**
"People and ecosystems are already suffering from the impacts of climate change across the world, and these impacts will worsen unless we move quickly to radically reduce global greenhouse gas emissions. But we've also let this problem get to the point where rapid emission reductions alone won't be enough—we also need to develop ways to remove large amounts of carbon dioxide from the atmosphere and to preserve critical parts of the Earth system while we still can."[18]

**Sir DAVID KING**
“Today the level of greenhouse gases (GHGs) 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.”[19]

[14] columbia.edu/~jeh1/mailings/2021/NovemberTUpdate+BigClimateShort.23December2021.pdf
[15] twitter.com/jrockstrom/status/1584811163329523712
[16] link.springer.com/chapter/10.1007/978-3-030-78795-0_2
[17] newscientist.com/article/mg20126971-700-how-to-survive-the-coming-century/
[18] phys.org/news/2021-06-carbon-emissions-expert.html
[19] breakthroughonline.org.au/dor

Until emissions reach zero, CDR complements decarbonisation in mitigating the rate of increase of $CO_2$. After that point, CDR can reduce the absolute level of $CO_2$, but it is a relatively slow process, and not a primary tool in countering a locked-in temperature rise of 1.5˚C by around 2030, and likely warming of 2˚C before 2050 unless there is a radical reduction in emissions far beyond current national commitments.

## Repair with albedo modification

Albedo modification (AM) is the reflection of more sunlight away from the planet. Options include:

- 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 bounded by material or energy use constraints. MEER addresses the imminent urgency of climate change due to temperature increase and weather extremes while reshaping energy production and consumption to renewable energy.[20]
- Marine cloud brightening (MCB) to increase reflectivity, in which 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,[21] and the Centre for Climate Repair at Cambridge is urgently researching MCB as a means of cooling the Arctic.
- Solar radiation management (SRM), more accurately described as stratospheric aerosol injection (SAI), which increases the amount of stratospheric aerosols 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, but with potentially significant risks.
- Increasing reflection of the terrestrial surface, 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.

Some of these are at the early stage of research, whilst others have been more extensively researched, such as SAI. All are at a relatively low level of technical readiness.

Unlike CDR, albedo modification cannot 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, in theory, "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."[22]

---

[20] prweb.com/releases/harvard_faculty_ye_tao_presents_a_solution_to_the_climate_change_crisis_at_nanoscientific_symposium_nov_19_2019/prweb16688571.htm
[21] nature.com/articles/d41586-021-02290-3
[22] agu.org/Share-and-Advocate/Share/Policymakers/Position-Statements/Climate-Intervention-Requirements

## Climate records to mid-2023

- July was the hottest month on record, at between 1.5–1.6˚C, depending on the dataset used.
- July 2023 set a new global record for the warmest July by an extremely large margin, around 0.3˚C, reflecting the combination of human-driven warming, a growing El Niño event, plus other factors such as stratospheric water vapour from the 2022 eruption of the Hunga Tonga-Hunga Ha'apai volcano in the South Pacific, and a phase-out of sulphur in marine shipping fuels which reduced the temporary aerosol cooling, and a higher level of total solar irradiance..
- Record-setting global temperatures in June and July have been accompanied by record heat waves in many regions:
  - Italy's Rome shattered its highest temperature record (set only last year in 2022) by 2°C on 18 July, seeing 42.9°C. A scorching 48C was recently reported for Sardinia.
  - Parts of the USA have been baking under record-setting persistent heat, with Phoenix in Arizona setting a record of 31 days in a row over 43˚C.
  - China also set a provisional new national temperature record of 52.2˚C.
  - In the southern hemisphere winter, temperatures in early August included more than 37˚C in the mountain town of Vicuna in central Chile.
- The extreme heat in 2023 likely contributed to wildfires in places such as Canada, Turkey and Croatia. In Canada, fires have burned a record 27 million acres so far in 2023, an area larger than the country of Portugal.
- The oceans have been unusually warm with an unprecedented spike, reaching an all-time average daily global sea surface temperature in early August of 20.96˚C. Warmer waters have less ability to absorb carbon dioxide.
- Antarctic sea ice has set new all-time low records for most of 2023 and has been far below average for the past few months in a manner that has astounded scientists.
- 2023 is more likely than not (e.g. >50% chance) to end up as the warmest year on record.

Source: Adapted from Carbon Brief[23]

## Resources

Some climate intervention research and advocacy groups:

- The Degrees Initiative, degrees.ngo
- Silver Lining,  silverlining.ngo
- Climate Crisis Advisory Group,  ccag.earth
- Climate Overshoot Commission, overshootcommission.org
- MEER, meer.org

[23] carbonbrief.org/state-of-the-climate-2023-now-likely-hottest-year-on-record-after-extreme-summer