GEOENGINEERING

Do we need climate interventions?

Geoengineering sounds like the stuff of science fiction. But the longer meaningful emissions reductions are delayed, the more likely it is that we'll reach for radical – and risky – climate solutions. *Jennifer Johnson* evaluates the options.

When the Philippines' Mount Pinatubo erupted on 15 June, 1991 it spewed a cataclysmic cloud of rock, ash and gas 35 km into the air. Debris was found as far away as the Indian Ocean. While larger particles fell out of the sky fairly rapidly, sulfate aerosols lingered in the stratosphere – preventing solar energy from reaching the Earth's surface as normal. It's now believed that the eruption cooled the planet by around 0.5°C for more than a year.

In an age of accelerated global heating, it's little wonder that scientists are interested in finding ways to mimic Pinatubo's cooling effect.

Spraying aerosols

The concept of geoengineering – or deliberate intervention in the Earth's climate systems – has existed for decades. But it hasn't resembled anything close to a credible scientific proposition until recently. This summer, Harvard researchers plan to launch a test balloon over northern Sweden in the first stage of an experiment that would inject radiation-reflecting particles into the stratosphere. The flight is not the experiment itself, but a trial of its equipment without the release of any particles.

If the initiative eventually wins the approval of an independent advisory committee, the Harvard team will release a small amount of calcium carbonate at a height of 20 km into the atmosphere. The aim is to create a 'perturbed air mass' that measures about 1 km in length and 100 m in diameter.

The team behind the experiment hopes to improve scientific knowledge of stratospheric aerosol physics and chemistry relevant to solar geoengineering. They're not creating a blueprint for the large-scale release of reflective particles into the atmosphere so much as trying to understand the mechanics of doing so.

In February, several Swedish environmental groups, including Greenpeace Sweden and Friends of the Earth Sweden, wrote to the country's government and the Swedish Space Corporation to oppose this summer's test balloon flight. In letters seen by *the Guardian* newspaper, the campaigners warned that the test could mark the first step towards the use of a potentially 'dangerous, unpredictable and unmanageable' technology. Similar arguments have been made in opposition to geoengineering initiatives in the past.

Detractors have long warned that solar geoengineering of the kind proposed by the Harvard researchers could change the planet beyond recognition. Environmentalists also worry that placing our faith in far-off tech fixes could stall action on emissions today. But if the only alternative is runaway climate change, spraying aerosols into the atmosphere could increasingly seem like a rational course of action.

Reflecting sunlight

Geoengineering techniques are usually divided into two categories: solar radiation management (SRM) and carbon dioxide removal (CDR). The former is concerned with reflecting sunlight back into space, while the latter is focused on capturing and sequestering greenhouse gases. There are two SRM methods currently in the earliest stages of research and development. One of them is stratospheric aerosol injection – the tactic proposed by the Harvard team – and the other is known as marine cloud brightening (MCB).

Scientists in Australia carried out the first outdoor MCB experiment at the Great Barrier Reef in March 2020. Earlier that year, the reef had undergone its most severe mass coral bleaching event to date, impacting the full length of the 2,300 km marine ecosystem. It's thought that MCB, which involves spraying sea salt particles into ocean clouds to help them reflect more sunlight, could lessen the severity of coral bleaching during marine heat waves.

Scientists have proposed using marine cloud brightening to protect delicate ocean ecosystems from marine heatwaves

In the experiment, a modified turbine fitted with 100 high-pressure nozzles was fixed to the back of a boat, which sprayed trillions of tiny salt crystals into the air above the reef.

The team behind the project, led by researchers from the Sydney Institute of Marine Science and Southern Cross University, tested the technology at one-tenth of the scale they're eventually aiming for. By next year, they hope to have their technology ready at full scale – meaning that they're able to brighten clouds across a 20-by-20 km area. It's not yet known whether MCB could alter rainfall patterns over land or sea, though scientists will also study these risks as the project evolves.

However, the project's leader, Dr Daniel Harrison of Southern Cross University, has emphasised that MCB is no replacement for much-needed emissions reductions. 'Cloud brightening could potentially protect the entire Great Barrier Reef from coral bleaching in a relatively cost-effective way, buying precious time for longer-term climate change mitigation to lower the stress on this irreplaceable ecosystem,' he said in a statement last April.

Many researchers involved in geoengineering believe that their techniques should only be deployed to buy time for the planet to decarbonise. This is the stated aim of the Arctic Ice Project, a California-based initiative that claims to be 'the most studied ice restoration effort in the world'. Started by Stanford University lecturer Leslie Ann-Field, the project is setting out to prove that a strategically-deployed layer of silica can improve the reflectivity of Arctic sea ice, thereby staving off dangerous melting while the global economy decarbonises.

The Arctic Ice Project is testing its materials and solutions on ice at two sites, one in Alaska and one in Minnesota. If all goes to plan – and it can be proven that the small, powder-like silica beads are safe – Field hopes to distribute them strategically across vulnerable areas of the Arctic. In an interview with the BBC last year, she called the project 'the backup plan I hoped we'd never need'.

Understanding criticisms

Climate advocacy groups, such as the Environmental Defense Fund (EDF), are broadly opposed to pursuing geoengineering, as they believe it presents ecological, moral and geopolitical concerns. However, EDF's official policy position states that engaging in transparent, small-scale field research to understand the implications of SRM techniques is 'prudent'.

The organisation also calls for governance regimes to be put in place with the very first experiments of this kind. The Natural Resources Defense Council and the World Wildlife Fund-UK have also voiced their cautious support for small-scale research in recent years.

Meanwhile, the Union of Concerned Scientists (UCS) has laid out its own criteria for small-scale atmospheric experiments. It stipulates that funding for any SRM activities must come exclusively from entities that 'support mitigation and adaptation as the first-line solutions to climate change' and that SRM research priorities must be agreed in collaboration with stakeholders in climate-vulnerable nations.

The wider scientific community has been similarly cautious in its rhetoric on geoengineering. In its landmark 2018 Special Report on 1.5°C, the Intergovernmental Panel on Climate Change (IPCC) acknowledged that stratospheric aerosol injection could 'theoretically' be effective in reducing temperatures.

But in its Summary for Policymakers, which presents the report's key findings, the group wrote that SRM methods: 'face large uncertainties and knowledge gaps as well as substantial risks and institutional and social constraints to deployment related to governance, ethics, and impacts on sustainable development'.

Ultimately, the hazards – and the potential benefits – of SRM have not yet been adequately explored through science. Whether they ever should be is an ongoing point of debate. Some critics worry about the so-called 'moral hazard' effect, in which funding research into geoengineering prevents policymakers from taking greenhouse gas mitigation seriously. Others are concerned that if a global-scale project were undertaken, and then geopolitical conditions conspired to halt it in-progress, temperatures could rapidly rebound to the detriment of ecosystems.

There's no doubt that policymakers will have to answer some highly consequential questions about geoengineering in the near future. Namely, do we have too much to lose to fund SRM, with all its potential knock-on effects? And when do we have nothing left to lose?

Some critics worry about the so-called 'moral hazard' effect, in which funding research into geoengineering prevents policymakers from taking greenhouse gas mitigation seriously

Carbon dioxide removal

The issue of carbon dioxide removal (CDR) is somewhat less controversial than SRM. This is because there's a strong consensus around the fact that accumulated CO_2 will have to be removed from the atmosphere, in addition to emissions abatement measures. The concept of CDR has also attracted a great deal of attention in recent months, thanks largely to the intervention of high-profile tech giants.

In February, Tesla founder Elon Musk revealed he would offer a $100mn prize for the best carbon removal technology. The four-year competition invites inventors to create and demonstrate 'solutions that can pull carbon dioxide directly from the atmosphere or oceans' with the ability to scale 'to gigatonne levels'. Any 'carbon negative' solution is eligible to enter the competition – from direct air capture technologies to nature-based CO_2 sequestration methods.

Just a few days prior to Musk's announcement, Microsoft said its climate fund would invest in the Swiss direct air capture (DAC) firm

CO_2 removal methods

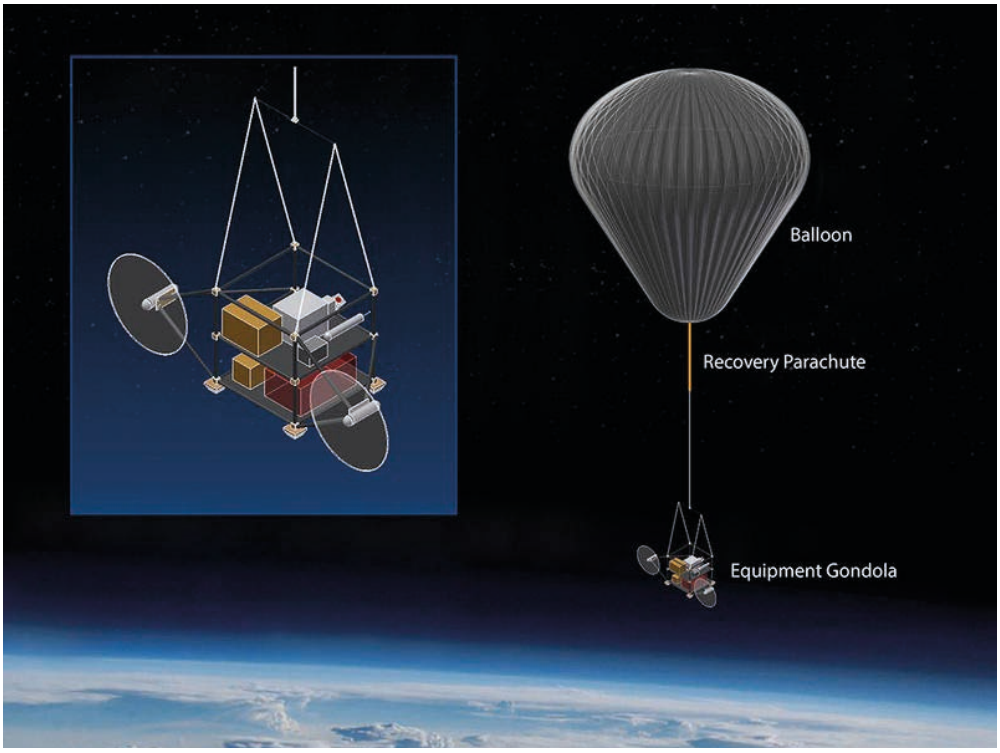
There are numerous theoretical options for carbon dioxide removal, most of which have only been tested on a limited scale – if at all. Here are some of the most popular suggestions, and the challenges associated with them.

Afforestation – tree planting on a global scale is a politically popular option, though it will come with land-use challenges. For instance, planting trees on arable land could reduce food supplies. The threat of disease and destruction also make forests unreliable long-term carbon stores.

Biochar – adding a charcoal-like material to soil can prevent plant matter from breaking down and releasing CO_2, meaning that it's essentially locked up in the soil. However, more research is needed to determine this method's logistical viability on a global scale.

BECCS – bioenergy with carbon capture and storage can, in theory, offer net carbon removals. CO_2 is drawn down when biomass is grown, and technology could capture and store the resulting emissions when it is burned to create energy. The use of waste feedstocks would help to allay land-use concerns, though careful lifecycle accounting is needed to ensure projects are genuinely negative emissions overall.

Ocean afforestation – similar to terrestrial afforestation, this proposal would involve growing kelp and other microalgae, which are highly efficient stores of carbon. One 2019 study suggested farming seaweed on an industrial scale before harvesting it and sinking it in the deep ocean, where carbon could be stored indefinitely. However, more research on seaweed's CO_2 sequestration potential is needed before such projects can be pursued.



The proposed delivery system for Harvard's stratospheric aerosol injection experiment.
Image: Harvard University

Climeworks. More specifically, it will offer backing to the company's existing project in Iceland, which uses fans to capture carbon from the air before pumping it into the ground for long-term storage. In some cases, Climeworks also sells concentrated CO2 to beverage companies and other industrial users. Microsoft's investment comes as part of its plan to reach 'negative' emissions by 2030.

DAC advocates argue that using machines to 'scrub' CO2 from the air is a highly-efficient approach to CDR. This is because other proposed removal methods, such as afforestation or bioenergy with carbon capture and storage (BECCS), require large amounts of land. But this is not to say that DAC is without its drawbacks. It's presently very expensive and highly energy intensive.

One study, published in 2019 in the journal *Nature Communications* found that if DAC were deployed around the world, it could require up to 25% of the global energy supply by the end of this century.

Considering the challenges associated with geoengineering methods, be they SRM or CDR techniques, it's clear that rapid CO2 emission abatement is still the preferred way forward. But given that emissions remain stubbornly high today, it's understandable that scientists want to prepare for all eventual outcomes. As such, it seems important to study and understand the consequences of geoengineering – well before radical climate intervention becomes a foregone conclusion. ●