THE BIG BAD FIX

The Case Against Climate Geoengineering

Acknowledgements

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Preface

As a rapidly warming world manifests heat waves, floods, droughts and hurricanes, geoengineering – large-scale manipulation of the Earth's natural systems – is being presented as a strategy to counteract, dilute or delay climate change without disrupting energy- and resource-intensive economies. Alarmingly, current debates about this big techno-fix are limited to a small group of self-proclaimed experts reproducing undemocratic worldviews and technocratic, reductionist perspectives. Developing countries, indigenous peoples, and local communities are excluded and left voiceless.

As this report details, each of the proposed geoengineering technologies threatens people and ecosystems. Holistic assessments of the technologies also show that if deployed they are highly likely to worsen rather than mitigate the impacts of global warming. The irreversibility, risk of weaponization, and implications for global power dynamics inherent in large-scale climate geoengineering also make it an unacceptable option. In 2010, governments in the Global South took the issue to the UN Convention on Biological Diversity (CBD) and achieved a de facto moratorium on geoengineering deployment and outdoor experimentation.

So why are we now seeing an escalating discourse around geoengineering? In short, the "tyranny of urgency" of climate change is being harnessed to push the debate on geoengineering from academic papers and computer models to climate policy arenas and – even more importantly – to outdoor experiments.

There is an urgency, of course. Post-Paris Agreement, governments must acknowledge that traditional, light-touch emission reduction strategies are not enough. We need an honest conversation about radical emission reduction pathways that transcend mainstream economic thinking.

We also need sound, socially-just and culturally-appropriate strategies to repay our land-carbon debt by vastly, yet carefully, restoring natural ecosystems. Avoiding efforts to address the root causes of climate change, and focusing on end-of pipe geoengineering technologies, is a political choice, not a destiny. It says that it is more acceptable to risk irreparable harm to our planet than alter the dominant economic system. It is not a technical or scientific necessity – it is a defence of a failed status quo that continues to protect the riches of the few.

Avoiding efforts to address the root causes of climate change, and focusing on end-of pipe geoengineering technologies, is a political choice, not a destiny.

'The Big Bad Fix' expands and updates the 2010 report, "Geopiracy". Jointly authored by the ETC Group, Biofuelwatch and the Heinrich Böll Foundation, it offers NGO activists, social movements, policy makers, journalists and other change agents a comprehensive overview of the key actors, technologies and negotiating fora of geoengineering. It also provides an analysis and history of the debate, the various interests shaping it, and case studies on the most important technologies and experiments. It argues for an urgent and immediate ban on the deployment and outdoor testing of climate geoengineering, overseen by a robust and accountable multilateral global governance mechanism.

A debate about geoengineering and its governance is needed, but it must be a broad, participatory and transparent debate from the grassroots, grounded in international law, built on the precautionary principle and informed by a rigorous understanding of real, existing, transformative and just climate policies and practices. We need a movement of movements coming together to oppose geoengineering as a technofix and false solution to the climate crisis and refocus on real changes. A movement that starts with communities and civil society organizations. A movement of movements that demands Hands Off Mother Earth!

1 December 2017

Barbara Unmüßig, President, Heinrich Böll Foundation
Pat Mooney, Co-founder, ETC Group
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Chapter 1

Geoengineering: The Emperors' New Climate

A New, Environmental Empire

Geoengineering has come to mean large-scale, intentional human manipulation of climate or Earth systems. Despite a long history of discussion within military contexts, today geoengineering is less often discussed as a technology of war and more often presented as a risky but potentially necessary techno-fix for climate change, a prudent insurance policy in the event of an imminent climate crisis. This report details the geoengineering technologies under consideration and describes the actors and the fora contemplating and/or addressing geoengineering. The case studies make clear the extent of work already underway on multiple geoengineering techniques and they identify impacts and implications of solar radiation management (SRM) and carbon dioxide (CO_2) removal techniques (CDR), the prevailing categories of geoengineering techniques. The authors also discuss the current proposals for geoengineering governance, including the history and power plays – and they summarize the arguments for and against. Perhaps most importantly, this report shows that in the post-Paris[1] era of climate change studies, conferences and intergovernmental policy fora, geoengineering is becoming normalized, not as a prudent "Plan B" but as a virtually inevitable techno-tool – despite the lack of public understanding, and with disregard for the relevant moratoria agreed by United Nations (UN) bodies. We believe the world is sleepwalking toward a geoengineered future and that meaningful critical debate about geoengineering is urgent.

The reasons planet Earth is on this trajectory and what could be done to change course are outside the purview of the geoengineering project.

Empire's Techno-fixes

Miracles once conjured by storytellers and conveyed by the writers of scripture are now the purview of technologists. We have, in fact, become routinely successful at local level 'miracles': we can ask a box on our coffee table how to dress a wound and to order bandages to our door. Sometimes, we can even help the blind see, the disabled walk and bring the seemingly dead back to life. And we have expanded our miraculous capabilities beyond the local to the global: we have learned to fly across oceans and into the cosmos. We are now expanding our aspirations to the mining of both asteroids and sea beds, and some of us imagine breathing our last breath on Mars, as the inventor/investor Elon Musk aspires to do.[2] But some of the truly biblical-scale miracles – commanding rain and winds, darkening the sun, parting seas and turning back tides – are yet beyond our reach. Some technologists and some policymakers remain undeterred: they aspire to manipulate Earth systems, to realize geoengineering in order, they say, to block or delay climate change.

The hubris – and hope and potential harm – could not be greater. The projected assumption underlying geoengineering is that the planet is on course for climate change so chaotic, and devastating for so many, that there is no choice but to develop technologies that could reduce the damage or at least buy us time to better defend ourselves and our economies. (The reasons planet Earth is on this trajectory and what could be done to change course are outside the purview of the geoengineering project.)

To the vast majority of the world's people – those who have not been directly involved in climate change debates and have never heard of geoengineering – the prospect seems fantastical, arrogant, absurdly dangerous and a really bad idea. It seems impossible to believe that governments would seriously consider interventions in complex and interconnected Earth systems – systems that do not recognize national borders – and render humanity indefinitely dependent on a technocratic elite. Nonetheless, geoengineering has been put on the negotiating table.

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Geoengineering has been a behind-the-scenes topic of discussion in UN climate change negotiations for at least a dozen years, but has become an explicit focus since the 2015 Paris Agreement. The Intergovernmental Panel of Experts on Climate Change (IPCC) is known to be focusing on geoengineering extensively in preparations for its next Assessment Report (AR6)[7] due in 2021, as well as for a special report on the feasibility of keeping the Earth's temperature increase below 1.5°C at the end of this century.[8] The UN Framework Convention on Climate Change will consider the special report when it meets in 2018. Geoengineering has been positioned to play a central role in the geopolitics of global climate change.

Does the Emperor have Clothes?

Governments are taking the geoengineering techno-fix seriously. Beginning in the early 1990s, several countries (Germany, the United States, UK, Japan, Canada, Mexico, India, South Africa) invested in national and/or intergovernmental experiments exploring a form of carbon dioxide removal called ocean fertilization.[3] In addition, at least China, Russia and the Republic of Korea have conducted or are actively developing geoengineering experiments.[4] Scientific institutions in the US, China and Russia are examining techniques that could conceivably lower temperatures by blocking or reflecting sunlight (grouped loosely under the rubric "solar radiation management" or "albedo modification"). Some open-air experiments of these techniques have been announced and scheduled for as early as 2018.[5]

Since 2008, most OECD governments have either publicly or privately studied the so-called potential and uncertainties of geoengineering technologies. The US, UK and German governments have all released reports on the topic. Also since 2008, the national governments participating in three different United Nations fora have adopted moratoria or prohibitions on one or all geoengineering technologies.[6] Although some may consider the UN resolutions "soft law," they are significant because they were passed with the agreement (or acquiescence) of all Parties. Two United Nations bodies – the Convention on Biological Diversity and the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (known as "The London Convention") – actively monitor geoengineering to ensure the integrity of their resolutions.

Empirical Hubris in History

The Big Idea to intentionally modify the Earth's environment for hostile purposes is not new. Leonardo da Vinci joined forces with Niccolò Machiavelli in the early sixteenth century to divert the Arno River, hoping to starve rival Pisa and to give Florence a waterway to the Mediterranean Sea. However, the best-laid plans of one of the world's most famous inventors and one of the world's most infamous politicians – armed with a workforce of 2,000 men – crumbled under the weight of weather, miscalculation and corruption.[9]

More recently, the development of the atomic bomb by the United States, and its deployment in 1945, led to a flood of enthusiasm for using nuclear explosives to blast harbours in Alaska, and to widen and deepen canals and create an ice-free route through the Northwest Passage. Although debated and seriously considered, at least in some quarters, none of these projects got off the ground.[10] Except, of course, that atmospheric nuclear testing was – of itself – an indirect form of Earth systems modification. Despite concerns about creating a nuclear winter or irreparably changing Earth's magnetic field, the world's superpowers conducted hundreds of atmospheric nuclear tests during the 1950s, '60s and '70s,[11] defying opposition from affected countries and the United Nations itself. The nuclear powers granted themselves the moral authority to decide for the rest of us. They lied to their own people about the dangers of atomic radiation and about the real possibility that nuclear war could wipe out most of the planet.[12]

Although both Russia and the US were alarmed by the possibility of nuclear proliferation, they agreed to an "Atoms for Peace" initiative that spread nuclear technologies around the world in full knowledge that the development of nuclear power stations could – and, ultimately, did – bring with it nuclear weapons proliferation.

The aspiration to use nuclear power to engineer nature in the 1950s found expression in somewhat less fraught methods of weather and ecosystem modification in the 1960s and '70s. Having grown up with the madcap experiments of aviators offering to seed clouds and bring rain to parched Texas ranches, US President Lyndon Johnson was eager to test weather modification on a larger scale and for a greater cause. When a drought threatened famine in the state of Bihar in India in the mid-1960s, Johnson used food aid as leverage to strong-arm the Indian government into allowing the US Air Force to conduct cloud-seeding missions to try to end the drought.[13] There was no evidence that the seeding worked, but – as is the case with geoengineering experiments, in general – there was also no certainty that the cloud seeding had not helped, especially since the cloud-seeders failed to document how much rain fell to the ground.[14] Armed with that ambiguity, Johnson prevailed upon Ferdinand Marcos, the Philippines' dictator, to allow him to try weather modification over the country's entire archipelago in 1969.[15] Again, the results were inconclusive. Desperate to gain control of the Vietnam War, and spurred on by scientists who wanted to give weather modification another chance, Johnson, followed by Richard Nixon, used cloud seeding as clandestine warfare, with the purpose of rendering the Ho Chi Minh trail impassable.[16] For a third time, no conclusions could be drawn about the experiment's efficacy.

When, in 1971, an investigative reporter exposed the years of weather modification experimentation in Vietnam, the political furor was intense, and the US struggled to persuade friends and allies in the United Nations that the military use of weather modification was an aberration that would not be repeated.
In 1975, the Soviet Union and the US submitted identical draft texts to the UN for a treaty that came into force in 1978 as the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD).[17]

Signatories to the Treaty – including all of the major world powers, except France – pledged not to modify the environment for military purposes.

In the 40 years since its adoption, the ENMOD Treaty's prohibition on "military or any other hostile use" has frustrated some countries in the Global South, who couldn't help noticing that the so-called peaceful use of weather modification in India and the Philippines set the stage for the military use of weather modification in Vietnam. The military interest in climate manipulation (geoengineering) cannot be underestimated. It does not take a Machiavelli to realize that no country can cede control of the Earth's climate to other countries, and Machiavelli was probably not the first to recognize that the best defence is a strong offense. Were the defence agencies of major governments not researching (and even developing?) geoengineering technologies, their leaders would have cause to wonder at their negligence.

A "Climate of the Willing"?

Who wants geoengineering? For rhetorical purposes at least, nobody wants it. Even the most vocal advocates for investment in geoengineering research remind that intentional climate manipulation is currently far too dangerous, with too many unknowns, for governments to deploy it. A small but significant group of (mostly Western European and North American) scientists, however, has warmed to the idea of geoengineering the planet. Dubbed the "Geoclique"[18] by science journalist Eli Kintisch, this tight club insists that climate change is so obviously threatening that it is only reasonable to develop a "Plan B" because governments are failing to reduce GHG emissions as drastically as they should and, anyway, the level of carbon dioxide in the atmosphere may already be too dangerous. All of these reluctant visionaries emphasize their 'green' credentials and claim to work on behalf of the greater good. They are careful to passionately call upon governments to show leadership and slash emissions and they acknowledge the scientific uncertainties of their proposals. Nonetheless, they argue far and wide for investment in geoengineering research and make their case for technology development and experimentation. Harvard University professor David Keith's 2013 book, *A Case for Climate Engineering,* is just one example.[19]

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The Geoclique has been looking for support from high-profile philanthro-capitalists – most prominently, Bill Gates, who showed early interest in geoengineering.[20] More recently, Gates, along with other philanthro-capitalists, has contributed to Harvard's new Solar Geoengineering Research Program to the tune of $7 million.[21] However, the Billionaires' Club is not anteing up the kind of money that an SRM program and experiments would need to get off the ground. Regardless of the unknown work being taken up by defence departments, governments – excepting China and likely Russia – have been reluctant to do much more than support studies and conferences. As of this writing, there is no pile of money visible to the public to support the realization of the geoengineering vision. That may change.

The 2015 Paris Agreement bought policymakers time. Characterized again and again as a "landmark" decision, in actuality, the Paris Agreement allowed politicians to kick the can down the road past the next election cycle. Instead of committing to mandatory and deep emission cuts, they protected their economic status quo – including the enormously powerful fossil carbon industry and its trillions of dollars of reserve assets that would otherwise have been stranded. When the reckoning arrives in 2020 or shortly after, the climate data will be still more alarming, and they will tell us that the only 'solution' presented as drastic enough is a geoengineering techno-fix. The same fossil carbon industry boosters that got governments into this mess will then press for both solar radiation management and investments in their specialty "negative emissions" technologies, that is, bioenergy and carbon capture and storage.[22] The military, too, will be on alert for possible defensive (and perhaps covert offensive) action. The philanthro-capitalists may even step up their own contributions. An increasing number of academic scientists and environmentalists will get on board with "negative emissions" technologies (techniques to remove CO_2 from the atmosphere)[23] despite the dangers to land, water, food production, and rural and indigenous communities. The proven ways to reabsorb CO_2 – such as maintaining and restoring natural forests and other ecosystems with the communities that live within and alongside them and supporting peasant and agroecological food systems – will be abandoned.

Together or seeking other partners, these would-be Emperors could even form a "climate coalition of the willing" using geoengineering to try to protect their part of the Northern hemisphere, with little regard for the rest of the world.

We must remember that we are in a time of broad social discontent in which some economies are booming, but so is social and economic inequality. Multinational corporations have never been more powerful, and governments are struggling to keep up. Worse still, we have a White House that makes Richard Nixon's administration look like a paragon of transparency, and leaders in China and Russia who would not balk at using climate manipulation if they started to really feel the heat. Together or seeking other partners, these would-be Emperors could even form a "climate coalition of the willing" using geoengineering to try to protect their part of the Northern hemisphere, with little regard for the rest of the world.

The Emperors' new hose?

Research is needed. There is universal agreement on all sides of the geoengineering debate that we need to know much more about planetary systems than we do today in order to survive climate change. Indeed, the research agenda in some areas is compatible even if the goals are different. But there are some things we don't know we don't know – and that we must know before tampering with the global thermostat. In mid-2017, the world was surprised to learn that the largest network of volcanoes is not in East Africa but in West Antarctica: more than ninety volcanoes were discovered under four kilometers of melting ice.[24] Melting ice can change the pressure on the volcanoes, possibly causing eruptions. If the Antarctic gives us any powerful eruptions while the emperors are blowing sulfates into the atmosphere via a synthetic volcano to "manage" solar radiation, we could find ourselves more concerned about staving off an ice age than about global warming. Not long ago, we also learned that there is a fast river flowing underneath the Pacific Ocean, which was previously unknown[25] – and could significantly influence ocean upwelling or ocean fertilization. The question for geoengineers is, what else don't they know?

In the post-Paris era of climate change studies and policymaking, the notion that geoengineering is a viable stopgap measure to delay climate change is alarming. Without public awareness or inclusive, intergovernmental debate, geoengineering is becoming normalized. Policymakers are coming to believe that the Emperors' New Climate is unavoidable.

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The right of every country and every citizen to debate and to eventually either reject or accept climate techno-fixes must be affirmed. While countries enjoy sovereignty, geoengineering is a global concern and the debate must take place at the global level, including in the UN General Assembly, and in the context of the known climate change mitigation responses – even if they transcend conventional economic thinking and are opposed by vested interests.

We must remember that, while time is short, peoples and civilizations can often move very quickly. This is not to deny that CO_2 emissions are cumulative and that deep emission cuts in the immediate years and decades will not be enough at the end of the century. But we have demonstrated extreme flexibility before. Confronted with the immediacy of World War II, major industrialized powers transformed their economies almost overnight as North American urbanites sprang into action to grow "victory gardens" to ensure their food supply and, en route, gave themselves the most nutritious diet of the entire century. Think of the changes between 1920 and 2000: most of the technological advances that directly benefited health and wellbeing took place in the first decades of the twentieth century and – contrary to Silicon Valley's self-aggrandizement – actually petered out after 1970. The first conversations about climate change began in the 1960s, but may be taking root only today. Also, back in the 1960s, health concerns related to cigarette smoking were just beginning to grow and now the culture of smoking is in rapid retreat, at least in industrialized countries.

Peasants, small farmers and artisanal fishers could meet most of the challenges of climate change in this century if they are supported – not undermined. Policymakers must listen to peasants and not to the keepers of the agro-industrial food chain.

Although there is still a long way to go, social attitudes toward gender and, especially, the LGBTQ+ community changed enormously in many countries within a decade. Significant change may exhibit long periods of dormancy, but sudden shifts can happen in a matter of years.

Geoengineers – and many other concerned people – worry that food insecurity will increase as changing climatic conditions transform pests that affect crops and diseases that affect livestock, especially livestock already vulnerable from genetic uniformity. (These worries come with concomitant concerns about human health – including increasing antibiotic resistance.)

Yet, our historic experience is that farmers can, when necessary, adapt their production practices quickly. In less than 100 years, African farmers adopted and adapted the Western hemisphere's maize to almost every climatic condition across the continent without the benefit of trains, telegrams or technicians.[26]

Farmers in Papua New Guinea similarly adapted another new crop – sweet potatoes – and grew the crop for food and feed, from mangrove swamps to mountaintops and through 600 different languages, in less than 100 years.[27] Immigrant farmers brought seeds from Europe and adapted them across extraordinarily different climates and soils in North America within a single generation. Maroons from West Africa smuggled seeds from home and immediately adapted them to the Caribbean and South America within a growing season. Peasants, small farmers and artisanal fishers could meet most of the challenges of climate change in this century if they are supported – not undermined. Policymakers must listen to peasants and not to the keepers of the agro-industrial food chain, and policymakers should reject grant proposals for Bioenergy and Carbon Capture and Storage (BECCS)[28] that will block small farmers from their own sustainable climate mitigation strategies. Local cultivation systems and ecosystems must be protected and supported.

Geoengineering, through changing local weather, dimming the sun, affecting monsoon and wind patterns – as well as the associated battles over land, water and nutrients that large bioenergy plantations imply – are threatening peasants' abilities and livelihoods.

The modern era of wind and solar power, both of which have been with us for centuries, of course, was spurred in the 1970s by OPEC's oil embargo against the United States. When the embargo ended, so did most of the enthusiasm for alternative energy sources.

The greatest barrier to this progress is the fossil carbon industry, and the most pressing conversation we need to have is how to wind down that industry.

So far, in this century, the cost and efficiency of wind and solar energy have improved astonishingly. There is no technological reason to doubt that alternative energy sources could meet our needs and that fossil carbon could become unnecessary well before mid-century. The greatest barrier to this progress is the fossil carbon industry, and the most pressing conversation we need to have is how to wind down our fossil fuel industry.

This is not to ignore that climate change in this century will have major negative impacts. Agriculture, for example, will experience unprecedented challenges. We must strengthen resilient societies that are able to not only collaborate, but also to shift rapidly as need requires. But there is no need to surrender to the Emperors.

Safe, fair and ecologically sustainable solutions to the climate crisis

- Radical emissions reduction pathways integrated across sectors
- Politically managed and coordinated phase-out of fossil fuel infrastructure and production (including the early shutdown of existing oilfields, coalmines and fracking sites!)
- 100% decentralised energy supply from ecologically safe renewable sources such as solar and wind energy, with local communities' consent
- Changing high-consumption lifestyles and production chains
- Efficient communal and public transportation systems
- Absolute reduction in global resource and energy consumption, e.g., through circular economies and zero-waste strategies
- Vast, yet careful, ecological restoration of global ecosystems: forests, rainforests, moors and oceans, with full participation of the local communities that live in and maintain them
- Transformation of emission- and fertiliser-intensive agro-industrial chain towards food production based on peasant agriculture and smallholder farms
- Locally and ecologically adapted land use and farming practices, support for agroecology and peasant ecological production
- Support for local, peasant and small farmers' food markets

Chapter 2

Geoengineering: The Technologies

Hey, Geoengineers, what do you know?

We don't know how to "hack the planet" with geoengineering. We don't know how much it will cost – especially if or when geoengineering doesn't work, forestalls constructive alternatives or causes unintended, adverse effects. (However, proponents claim it will be inexpensive.[29]) We don't know how to recall a planetary-scale technology once it has been deployed. We don't know with any certainty what the impacts on human health and the environment will be. Geoengineers may drastically underestimate the difficulty of introducing a change into an ecosystem with predictable results – even a "softer," "gentler"[30] change, such as cutting down trees to expose fallen snow that will reflect sunlight away from Earth, or sprinkling CO_2-sucking sand on the ground. As much as the Industrial Revolution's unintended 'geoengineering experiment' (i.e., human-induced climate change) has disproportionately harmed people living in tropical and subtropical areas of the world, intentional geoengineering experiments are liable to do the same.

Geoengineering is the brainchild of engineers, not climate scientists, ecologists or sociologists. In order to design instruments blunt enough to have a dramatic impact on the world's climate, geoengineering proposals necessarily strip away some of the complexity of living, interconnected systems: Too hot? Block the sun! Too much CO_2 in the atmosphere? Put it underground! Scanning profiles of geoengineers, it is rare to find an oceanographer, geologist, atmospheric chemist or biologist.

The Keith Group at Harvard University, for example, with more than a dozen people working "at the intersection of climate science and technology...[focusing] on the science and public policy of solar geoengineering,"[31] has just one Earth Science (undergraduate) degree among them.[32] David Keith's own expertise is in physics (and more lately public policy).

Geoengineers may drastically underestimate the difficulty of introducing a change into an ecosystem with predictable results.

What's in a name?

Given the audaciousness of geoengineering proposals, it's no surprise that advocates have spent a lot of time thinking about (and re-thinking) how to frame them for the benefit of policymakers and the public. Two general taxonomic categories dominate: proposals that aim to lower the level of greenhouse gases in the atmosphere and those that aim to alter the amount of heat in the atmosphere – Carbon Dioxide Removal/Greenhouse Gas Removal (CDR/GGR) and Solar Radiation Management (SRM), respectively. A third category, Weather Modification, connotes rainmaking con-men and covert operations and is usually discounted, but there are intellectual and technical reasons to keep it in mind. Historian James Fleming has persuasively shown that climate engineering, with its "pathological" hype and "impoverished debate" – i.e., ahistorical and without social considerations – is the legitimate heir to weather modification.[33] And when geoengineering proponents argue that incremental, reversible climate interventions can be applied locally and at smaller scales, the technical distinctions between weather modification technologies become even less clear (see box overleaf).

What falls under the rubric of geoengineering and what doesn't is, in the end, a political question. Rachel Smolker, co-director of Biofuelwatch, explains "the potential for trickery in the game of defining, labeling and 'messaging' about climate geoengineering."[34] One maneuver to gain public and policy support for geoengineering is to refer to CDR/GGR and SRM technologies as examples of climate change "mitigation," as the IPCC has recently begun doing.[35] A decade ago, in the IPCC's 2007 Assessment Report (AR4), mitigation was understood to refer to human interventions that lower levels of greenhouse gases via increased energy and fuel efficiency, improved land management, composting, and the like.[36] Grouping together these techniques and SRM technologies is a radical – and alarming – departure for the IPCC.

Pushing for a narrow definition of geoengineering may exempt some consequential and controversial techniques such as afforestation (i.e., monoculture tree plantations) from international scrutiny. On the other hand, defining geoengineering broadly – setting white roof painting alongside SRM techniques, for example – may weaken vigilance and dampen resistance to the most extreme and untested technologies. Recent (thwarted) attempts to dump iron filings into the northeast Pacific almost evaded the notice of watchdogs – despite two international moratoria on ocean fertilization – partly because the expedition was framed as a "salmon restoration" project not an "ocean fertilization" experiment (see Chapter 3, Case Study III).

New attempts to re-brand geoengineering technologies include climate remediation, soft geoengineering or even geotherapy,[37] suggesting benign rehabilitation and restoration and/or incremental, local or 'lite' applications. When Ken Caldeira coined the term solar radiation management more than a decade ago (as a tongue-in-cheek nod to government bureaucratic-speak, according to Caldeira), he assumed its "boring, obfuscating" name would sound no alarms. Later, he thought it better to substitute reflection for the loaded term radiation, to little avail.[38]

As proponents try to rebrand geoengineering, we should not be distracted from scrutinizing the mechanisms of the proposed technical interventions, and their implications and potential impacts.

This chapter provides an overview of some of the proposed technologies. We group them according to the targeted environmental system (land, oceans, air) in order to put the emphasis on the system, but do not mean to imply that effects will be limited to only the targeted system. A manipulation of oceans will have an effect on cloud climatology and a manipulation of clouds will have an effect on oceans.[39] Just as there are "climate feedbacks," deployed geoengineering technologies will also produce feedbacks – except these will be known only in real time (as the effects are being produced in the real world).

Three categories of Geoengineering as proposed by geoengineers

Greenhouse Gas Removal (GGR) including Carbon Dioxide Removal (CDR)

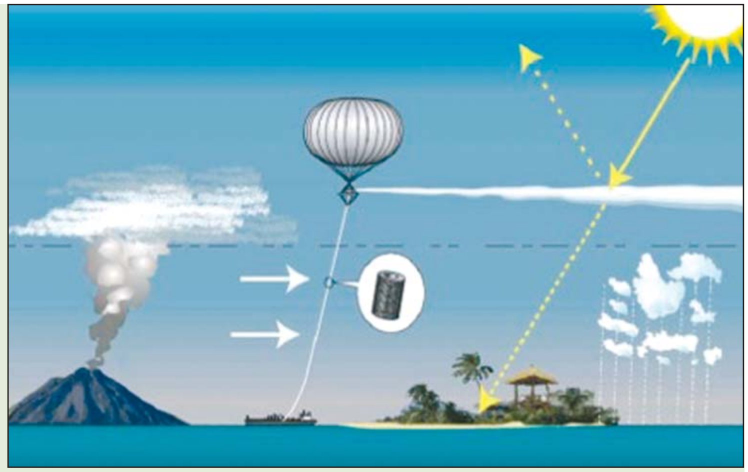
GGR and CDR refer to technological methods that attempt to remove carbon dioxide (CO_2) from the atmosphere after it has been released by activities like burning fossil fuels, deforestation or industrial agriculture. There are several proposed GGR/CDR technologies. Some aim to alter the chemical balance in the oceans to increase CO_2 uptake. Others are mechanical techniques to capture CO_2 at an industrial source and then bury it underground. Others propose to engineer plants to increase CO_2 "sequestration" capacity. While most proposals focus on CO_2 as the key climate-changing gas in the atmosphere (and are called CDR), use of the term "GGR" implies targeting any greenhouse gas, including, for example, methane or nitrous oxide.

To be effective, CDR in particular would have to be employed indefinitely in a coordinated way and on a global scale. It is uncertain how long and how well the CO_2 would remain sequestered and what the impacts would be for people whose livelihoods are most directly tied to the altered ecosystems. Despite stepped-up research on these technologies over the last decade, no one has yet been able to demonstrate that artificial, large-scale, long-term carbon sequestration is affordable, safe or even possible, or that CDR would produce the desired effect of lowering the Earth's temperature.

CDR technologies aim to remove carbon dioxide from the atmosphere after it has already been emitted. Photo (cc) Louis Vest

Solar Radiation Management (SRM)

SRM technologies aim to lower the amount of heat in the atmosphere by bouncing sunlight back into space before it becomes trapped in Earth's atmosphere by greenhouse gases, thereby lowering temperatures. Like GGR, SRM is an 'end-of-pipe' approach, meaning that the effort aims to reduce some of the damaging effects of high levels of greenhouse gases, not to reduce greenhouse gas emissions. The problem of ocean acidification would not be addressed – and could even be worsened – by some SRM techniques, for example. Techniques proposed or under research include everything from 'low-tech' reflective geoengineering (e.g., painting roofs and roads white to reflect sunlight) to extreme technologies such as stratospheric aerosol injection (SAI) and "space mirrors" made of extremely fine reflective mesh somehow placed between Earth and the sun.



SRM technologies aim to lower the amount of heat in the atmosphere by bouncing sunlight back into space before it becomes trapped in the Earth's atmosphere. Illustration (cc) Hugh Hunt

While each SRM proposal has its own implications, they share the aim of trying to induce a change in the so-called radiative balance of the planet – to push energy (in the form of sunlight) away from Earth instead of toward it so that it won't become trapped in Earth's atmosphere and cause temperatures to rise. SRM deployment is likely to alter the hydrological cycle (reduce or increase rainfall by changing weather patterns) and produce unequal effects across the planet, potentially threatening the sources of food and water for millions of people.[40] If SRM schemes are deployed at large scales and the technologies are suddenly stopped – due to ideological or economic shifts or because of wars or technology failures – dramatic global warming could occur with the removal of SRM's artificial cooling effect. This is sometimes referred to as termination shock.[41] Some commentators argue that termination shock could be avoided and they even supply an alternate (and they argue, "accurate") articulation of the concern: "Once you start SRM and it is exerting a fairly high degree of cooling, it cannot be stopped suddenly, but could be phased out over a long period."[42]

SRM deployment is likely to alter the hydrological cycle (reduce or increase rainfall by changing weather patterns) and produce unequal effects across the planet, potentially threatening the sources of food and water for millions of people.[40]

However, gradual phaseout would only be possible in the presence of a simultaneous safe and effective removal of greenhouse gases and halting of emissions and the possibility of gradual phaseout is still hypothetical!

Weather Modification

Modern efforts to control weather began as early as 1830 with rainmaking as well as rain-suppressing efforts[43] – the latter still a favorite technique in China to guarantee clear skies for important state events.[44] Though weather is understood to be a local phenomenon over a short period and climate refers to weather in a particular place over a long period (approximately 30 years), the two phenomena are related. As climate change produces more extreme weather events, interest in weather control will grow. Further, geoengineering techniques, intended to have an effect on climate, will also produce local weather effects. If, for example, "marine cloud brightening" (an SRM technique that aims to increase the reflectivity of clouds) were to be deployed simultaneously with cloud seeding (a weather modification technique that aims to increase rainfall), the likelihood of wacky weather increases. There are also geopolitical concerns. If governments ever gain control of changing the course of potentially damaging storms, diversions that direct storms toward other countries may be seen as acts of war.

Land: Geoengineering technologies that target terrestrial ecosystems

Carbon Capture and Storage (CCS)

CCS is largely aspirational, although it is an area of intense interest and some limited implementation. A CCS scenario would have CO_2 being continually extracted from smokestacks – or even car tailpipes – via "scrubbers" (likely using adsorbent chemicals), and then trapped, transformed into liquid and transported by pipeline to a (nearby) site where the liquid could be pumped underground in saline aquifers, oil or gas reservoirs, or under the ocean, to remain, theoretically, in long-term storage.[45]

CCS was originally developed not as a climate-change response technology but as an Enhanced Oil Recovery (EOR) technique. Pumping pressurized CO_2 into oil reservoirs to enhance oil production has been practiced for more than 40 years, particularly in the United States where it was developed to bolster domestic oil production. A recent report from the International Energy Agency's (IEA) CCS Unit describes "Advanced EOR+" as a way to "'co-exploit' two business activities": oil recovery and CO_2 storage for profit.[46] However, the IEA report notes the need for governments to create "a policy framework comprising multiple and complementary economic instruments," including tax incentives, for CCS to become economically worthwhile.[47] The CCS process is costly and technologically challenging (especially the "capture" and gas compression phases, which account for as much as 90% of the total cost of CCS).[48]

Kemper County Coal Plant, hyped as the US' first "clean coal" facility. Cancelled in June 2017 and developers are under investigation for fraud. Photo (cc) Wikipedia.

The symbiotic relationship between CCS and EOR undercuts its potential (even theoretical potential) as a serious climate-change response. All of the carbon captured from the only large-scale CCS-equipped power plant (coal) in the United States, Petra Nova in Texas, is transported 82 miles via pipeline to an oil field where it is injected for EOR.[49] Whether the injected greenhouse gases will remain safely stored, and for how long, is also uncertain. Leaks and venting are considered the greatest risks.[50]

Carbon Capture Use and Storage (CCUS)

Carbon Capture Use and Storage is an attempt to make CCS more profitable and perhaps uncouple it from EOR. CCUS implies the commodification of captured CO_2, which could be used as a feedstock in manufacturing and become effectively 'stored' in the manufactured goods. Scenarios are largely theoretical. One idea is to feed the captured CO_2 to algae in order to produce biofuels (which will [re]release the gas back upon use).[51] Another proposal is to react the captured gas with calcifying minerals to produce concrete for construction. The net energy balance is also questionable once full manufacturing costs are accounted for, as well as end-of-life considerations (for the manufactured goods or the biofuels) – meaning there may be a net increase in GHG emissions.

Bioenergy with Carbon Capture & Storage (BECCS)

BECCS refers to the capture and storage of the CO_2 emitted from bioenergy use. BECCS is touted as a "carbon negative" technology because it is based on plant-based fuels deemed "carbon neutral." (The plants "capture" and "store" carbon while they grow and are then used for fuel whose emissions are, in turn, captured and stored.) Climate scientists stress the unrealistic expectations for BECCS, which is, understandably, the policymaker's dream negative emissions technology. For example, "almost all of the scenarios with a likely chance of not exceeding 2°C and considered by the Intergovernmental Panel on Climate Change (IPCC) assume that the large scale roll-out of negative emission technologies is technically and economically viable."[52] Others point out that bioenergy crops imply land-use changes that will displace food crops, pastures, forests and/or people,[53] and that BECCS could keep the planet under a 2°C increase only by using at least 500 million hectares and as much as 6 billion hectares of land.[54] (See Chapter 3, Case Study I.)

Afforestation

Forests provide a variety of benefits (e.g., food, shelter, livelihoods), but they can also act as in situ carbon sinks. Afforestation, however, describes the planting of trees on lands that, historically, have not been forested.[55] Due to its potential carbon sequestration, some consider afforestation a geoengineering CDR technique.[56] Afforestation is promoted by governments and the private sector as a highly safe and cost-effective carbon-sequestration mitigation measure, but "planted forests," as the UN Food and Agriculture Organization calls them,[57] do not provide the same benefits as natural forests. Large monocultures of fast-growing, evergreen, often non-native species such as palm, pine, or eucalyptus are water-intensive and can lead to "green deserts" and degraded soils. Invasive tree species can spread to surrounding areas, where native species may not be able to compete. Climate change effects such as pest infestations, droughts and storms can affect the sequestration capacity of both natural forests and plantations. In recent years, countries with extensive monoculture tree plantations, such as Chile, Portugal[58] and South Africa,[59] have been hit by devastating fires.

Plantation proponents argue that "marginal" land is being put to good use,[60] but marginal lands are often used by communities for food and livestock-grazing. Even as a provider of local employment, tree plantations come up short due to poor working conditions and the intensive use of pesticides and fertilizers. The expansion of monoculture plantations is associated with increasing poverty rates[61] and communities and Indigenous Peoples have faced displacement, restricted access to land, and violence.

Ecosystem-destroying eucalyptus plantations would be a key part of a bioenergy with carbon capture and storage (BECCS) climate mitigation strategy.
Photo (cc) Chris Lang

Direct Air Capture (DAC)

Direct Air Capture is a largely theoretical technique in which CO_2 and other greenhouse gases are removed directly from the atmosphere after pollution has taken place. In some embodiments, very large fans move ambient air through a filter using a chemical adsorbent to turn the gas into a stream that could be stored, as in CCS. And like CCS, the fossil fuel industry is attracted to DAC because the captured CO_2 can be used to for enhanced oil recovery, especially where there is not enough commercial CO_2 available locally. However, DAC is not currently commercially viable because the technology removes CO_2 at very low levels and is energy-intensive, but some say DAC could be powered by nuclear power plants.[62] There is one demonstration facility near Zurich owned by Climeworks,[63] which aims to sells its captured CO_2 to customers in the food and beverage and energy sectors.

Enhanced weathering (terrestrial)

Here, mined olivine (magnesium iron silicate), which naturally takes up CO_2, is ground to a fine powder and spread on land to control levels of atmospheric CO_2.[64] The pulverized olivine would simply be dumped on beaches where wave action would, in theory, disperse it and cause weathering. Bio-uptake levels are still an unknown factor, as is the effect of large-scale dumping on the marine, terrestrial and freshwater environment. Massive mining operations to extract olivine would exacerbate mining's already disastrous effects on the world's ecosystems and local populations. Chemical effects of this mineral being added to other ecosystems are also unknown.

Biochar

Biochar describes a method of converting biomass into charcoal and then mixing it into soils to store the burnt carbon. Promoters of biochar point to the long and eco-friendly history of the Amazonian Terra Preta black soils, where indigenous groups bury charcoal and other organic matter to enhance their soil's fertility. Used on today's crops, however, the claim that biochar boosts agricultural productivity has not been consistently demonstrated.

Some proposals target municipal wastes as the biomass source. In order to have an effect, industrial biochar would require biomass plantations. In fact, in the first peer-reviewed biochar field trial, researchers were surprised to find that biochar-treated soils sequestered less carbon than other soils: adding more carbon stimulated the soil microbes to release more CO_2.[65]

Photosynthesis enhancement

These projects include work aiming to genetically engineer rice plants to exhibit the "more efficient" photosynthetic pathway properties of plants like maize and sugar cane. Rice is categorized a "C3" plant based on the way it converts CO_2 to carbohydrates; but if rice can be transformed into a "C4" plant, it is expected to fix carbon faster, resulting in more efficient water and nitrogen use and improved adaptation to hotter and drier climates. In 2008, the C4 Rice Project, later joined by 3to4, a European partner, kicked off with an $11 million grant from the Bill & Melinda Gates Foundation. Critics question the wisdom of using rice as the target crop in a time of water stress, and they worry that there is a high risk of failure – a functional C4 rice crop isn't expected for almost a decade.[66]

High albedo crops

Researchers are proposing to genetically engineer crop plants in major agricultural areas to give the plants more reflective leaves.[67] Little is known about the effects of increased reflectivity on the nutritional content of the plants, their photosynthetic capacity or on surrounding soil. Genetically engineered plants could spread their "reflectivity" to other relatives, with unknown consequences.[68]

White Out: Surface Albedo Modification

- **Desert covering:** More than a decade ago, entrepreneur Alvia Gaskill laid out a scheme to cover a significant portion of the world's deserts with white, polyethylene film to reflect sunlight and lower surface temperatures.[69] Deserts have plants, animals and people living in them, and it is difficult to imagine life continuing in a plastic-covered ecosystem. Cooler desert temperatures may also bring unexpected changes. Like many geoengineers, Gaskill suggests if there are too many political, ecological or weather challenges (the plastic has to be kept in place for several hundred years, for example), the projects could be local. However, local applications would have a minimal climate effect and would not justify the expense and disruption.
- **Ice covering:** Similar to desert covering, coatings – perhaps a nanotech film or small glass beads – would be applied to Arctic ice as a "reflective band aid" to insulate rapidly melting snowpack and glaciers.[70] An experimental project championed by Leslie Field, an engineer at University of California, Berkeley, with a resumé that includes work for Chevron and Hewlett Packard, has used regular plastic garbage bags, among other materials, to do this in Canada and California, and she has set up a crowd-funding site to expand the project.[71] Possible negative effects – including to weather, water temperature and biodiversity, and the environmental impact of the covering material itself – appears not to have been considered.
- **White Blankets:** roofs and pavements, plus mountaintop painting: In 2010, the World Bank famously awarded a small research grant to the winner of a "100 Ideas to Save the Planet" competition so that he could paint a Peruvian mountaintop white.[72] In academic circles, Hashim Akbari, a civil engineer at Concordia University in Montreal, has promoted the idea of government grants to cover rooftops and tarmac with white paint.[73] While painting roofs could have some local cooling effects, the painting of mountaintops would negatively affect fragile ecosystems, flora and fauna – but seems unlikely to proceed.
- **Snow Forest Clearance:** another idea, also adapted from engineering models, is to clear the planet's remaining areas of boreal forest (largely in Russia and Canada) to boost reflectivity. Studies by forestry schools at Yale, with partial funding from the US Department of Energy, indicated at least local cooling effects. However, these "white deserts" could destroy sub-arctic ecosystem productivity, affecting the caribou, migrating birds and other fauna, as well as plants and people that depend on them.[74] Proponents admit that there are many complexities. There would be a one-time (although final) bonanza for timber companies.[75]

Oceans: Geoengineering technologies that target marine ecosystems

Ocean Fertilization (OF)

In theory, carbon dioxide can be sequestered in the ocean, already the planet's largest carbon sink. Ocean fertilization refers to dumping iron filings or other "nutrients" (e.g., urea) into seawater to stimulate phytoplankton growth in areas that have low photosynthetic production. The idea is that the new phytoplankton will absorb and draw down atmospheric CO_2 and, when they die, the carbon will be sequestered along with their bodies on the ocean floor. However, scientific studies have shown that much of the carbon will be released again via the food chain. In addition, too much phytoplankton can disrupt the marine food web and create toxic algal blooms[76] and the presence of iron or urea can cause mineral and nutrient imbalances in an already stressed and acidic ocean environment. (See Chapter 3, Case Studies III and IV.)

Enhanced Weathering (marine)

This technique, similar to treating acidic agricultural lands with lime, proposes adding chemical carbonates to the ocean to theoretically increase alkalinity and therefore carbon uptake. The rate at which these minerals would dissolve, as well as the expense involved in amassing and dispersing enough of them to make an impact, is a major practical concern, as is its effect on the complex ocean ecosystem.[77] The increased demand for minerals would translate to increase mining activities,[78] which would have deleterious effects on land and biodiversity, which then rebound to the climate.

Algal blooms are proposed as a carbon dioxide removal technology because they increase carbon uptake in the oceans. Photo (cc) NOAA Great Lakes Environmental Research Laboratory.

Artificial upwelling

This proposal relies on the possibility of developing a technique to artificially pump up cooler, nutrient-rich waters from the depths of the oceans to the surface, in order to theoretically stimulate phytoplankton activity and then draw down CO_2, as in Ocean Fertilization (OF), above. It suffers from many of the same problems, including food chain disruption and dubious long-term efficacy. As with OF, it is based on a false equivalency between the complexities of natural upwelling events and artificial ones, and ironically, this method may also "upwell" already sequestered CO_2 in the form of dead or living sea creatures, allowing it to escape. The water temperature changes can also affect weather.[79]

Crop residue ocean permanent sequestration (CROPS)

This technique with a clever acronym but simplistic theoretical basis describes dumping tree logs or any biomass (e.g., crop waste) into the sea, in hopes that it will sink to the bottom and remain there, theoretically sequestering its carbon in the deep ocean.[80] However, it's likely the biomass will be broken down by the marine food web and the carbon will be (re)released. There are also concerns about the unknown effects on the marine ecosystem and the impacts of sourcing and transporting large enough quantities of biomass.

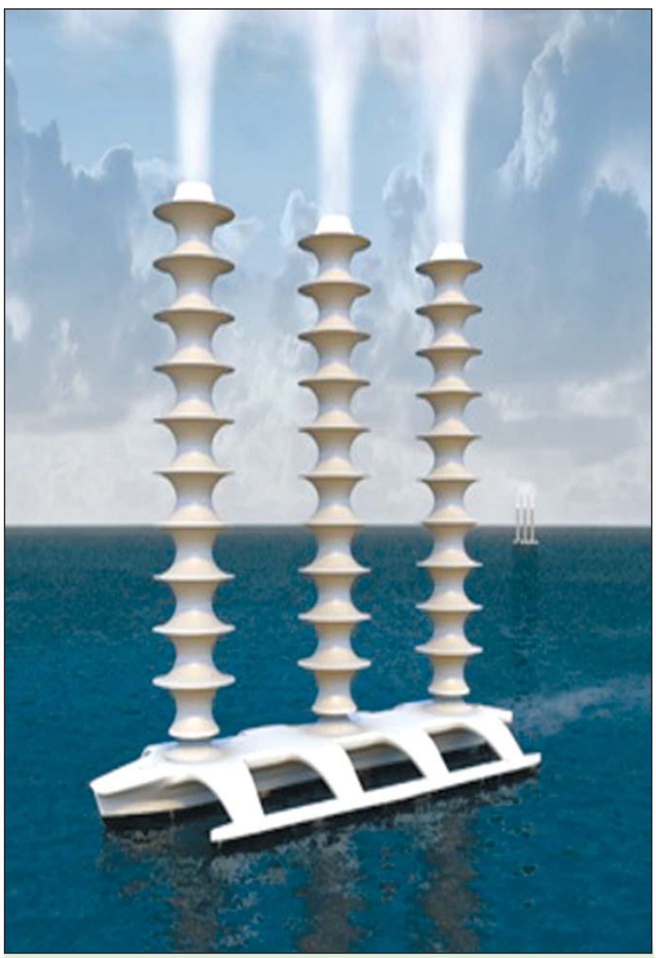
Microbubbles and Sea Foams

Another geoengineering physicist, Russell Seitz at Harvard, has gained attention[81] for his "bright water" albedo proposals. Seitz believes the answer to cooling the planet lies in bubbles: pumping tiny microbubbles into the oceans would, in theory, increase ocean surface reflectivity by thickening natural sea foams.[82] Other suggestions are for chemical foaming agents, kept buoyant by latex or other material, to be spread across the surface of the Earth's seas and other large bodies of water. Critics point out that deployment on the scale required to have a climate impact could increase ocean acidification and disrupt the entire basis of ocean and freshwater life dependent on access to light – from phytoplankton to dolphins.[83] It would also reduce oxygen in the upper layers of the ocean, where most fish and other species live. Seitz is pushing ahead with a microbubbles business start-up and discussion on this technique has focused more on the mechanical aspects (e.g., how to make the bubbles last a long time, whether to add latex or polystyrene, how will they be generated) rather than the biological or systemic implications.

Engineering global heat flows on a geoengineering scale

As ocean currents like the Humboldt and the Gulf Stream change – becoming colder with melted glaciers or warmer with global change – engineers in particular have become interested in intentionally altering ocean currents, changing the course of rivers or redirecting glaciers to lower the Earth's temperature by mechanical means. Using heat-exchange methods, massive ocean pumping or river reversal through dams, these are projects to 'remake the Earth' more irrevocably and radically than humans have already attempted. Numerous schemes are now getting attention.

As one example, two mechanical engineers from the University of Alberta in Canada reviewed several proposed marine downwelling techniques, and suggested that "formation of thicker sea ice by pumping ocean water onto the surface of ice sheets is the least expensive of the methods identified for enhancing downwelling ocean currents."[84]



Marine cloud brightening involves spraying sea water droplets to create "whiter clouds" that reflect more sunlight back into space. Photo (cc) NASA

The engineers were interested in the engines required, the fuel for the engines, carbon and ice contents, and different mechanical methods, while the effects on weather, ecosystem, species survival, fisheries and land masses were not explored in any significant way. Even the researchers, however, admit that "modifying downwelling ocean currents is highly unlikely to ever be a competitive method of sequestering carbon in the deep ocean, but may find future application for climate modification."[85]

Air: Geoengineering technologies that target the atmosphere

Stratospheric Aerosol Injection (SAI)

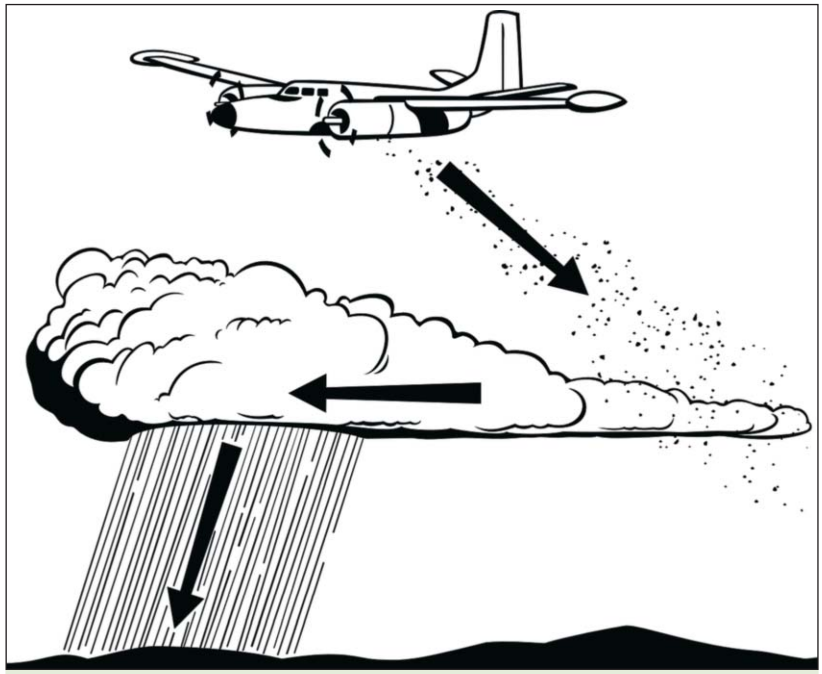
The prevailing SRM technology, SAI, involves releasing inorganic particles such as sulphur dioxide into the upper layer of the atmosphere – via cannons or hoses or aircraft – to act as a reflective barrier to reduce the amount sunlight reaching Earth. Sulphate injection is getting the most attention, but the unknowns are many, including the possibility of ozone layer depletion and significant weather pattern changes. (See Chapter 3, Case Studies VI and VII.)

Marine Cloud Brightening (MCB) or Increasing Cloud Cover

Cloud seeding technologies have been deployed for decades in (at least) the US and China to attempt to increase precipitation by spraying chemicals like silver iodide into clouds – despite continuing uncertainty about its effectiveness in actually changing weather as intended. Manipulating cloud cover and rainfall to increase reflection of sunlight back to space is a new, proposed SRM technique. Proponents aim to increase cloud condensation nuclei (the tiny particles around which clouds form) in order to create whiter clouds by shooting particles (salt from seawater droplets or bacteria) into them. One high-profile engineering proposal to increase cloud cover involves spraying salty seawater from land or via many thousands of robotic boats into marine clouds.[86] However, MCB, like all SRM, will have impacts on weather patterns – thicker clouds may not release rain predictably – as well as on marine and coastal ecosystem life. Who would decide where to put these possibly drought- or flood-causing clouds? (See Chapter 3, Case Study VIII.)

Cirrus Cloud Thinning

This SRM-related technology involves not thickening or adding cloud cover to increase reflection as in MCB, but thinning the wispy, elongated "cirrus" clouds of high altitudes. Dispersing them could, according to researchers Ulrike Lohmann and Blaž Gasparini from the ETH Zurich, allow more heat to escape into space and thereby cool the planet.[87] The researchers admit that the ice-nucleating particles that would be seeded into the high-altitude clouds may produce the opposite effect (e.g., it may thicken them, so that even more heat is trapped). Other researchers writing in the *Journal of Geophysical Research: Atmosphere* underscore the risks of unpredictable side effects of cirrus cloud thinning.[88]



Cloud seeding is a form of weather modification that involves injecting small particles into the sky to increase rainfall.

Storm Modification and Suppression

These attempts at modifying extreme weather events include efforts to redirect or suppress storms such as hurricanes and typhoons, including altering the surface temperature of the ocean with films of nanomaterials that would delay heat convection, or trying to change cloud composition. Storm modification aims to redirect or reduce the intensity of a storm, but geopolitical concerns – including the existence of the UN ENMOD Treaty that prohibits hostile uses of weather modification – as well as the difficulty of confidently measuring the results of the intervention have kept the research somewhat under wraps (see discussion in Chapter 1). It is a controversial area of research, but with enormous potential for profit.[89] Intellectual Ventures, which names Bill Gates as an investor, has applied for patents on some storm modification techniques.[90]

Space Sunshades

This proposal, researched by NASA and MIT, refers to the dispersal of "trillions" of small, free-flying spacecrafts launched a million miles above the planet to create a cylindrical artificial cloud. A 60,000-mile-long cloud of tiny objects could in theory divert 10% of the planet's current dose of sunlight back into space. Designing, manufacturing, launching, operating and monitoring such spacecraft is daunting, to say the least.

Solar sunshades would, quite literally, dim sun. While it's difficult to take the proposal seriously, inventor, astronomer and physics Nobel Prize-winner Roger Angel is suggesting a similar proposal using space mirrors (see below) as well. Angel is best known for revolutionizing telescope mirrors and is also working on improving solar energy collection with space telescopes.[91]

Space Mirrors

When somehow positioned in just the right place between the Earth and the sun, space mirrors could block 1-2% of the planet's sunlight, significantly cooling it. The idea was first floated by Lowell Wood of Lawrence Livermore National Laboratory in the early 2000s, and has inspired graphic designers ever since. Even simplified computer models of a space mirrored-world suggest mixed results, however.[92] The cooler planet would still have ocean levels rise as poles melted, and there could be increased drought in about half the world. There were no calculations about the effects of a dimmed planet for biodiversity and human and animal health. These schemes are extremely expensive and so far, technologically impossible; nonetheless, they garner enthusiastic media interest.[93]

Chapter 3

Case Studies

Case Study I: Bioenergy with Carbon Capture and Storage

Of the current Carbon Dioxide Removal (CDR) approaches on offer, bioenergy with carbon capture and storage (BECCS) has taken center stage – as a "mitigation" climate response and as a "negative emissions" technology.[94]

BECCS is the climate policymaker's dream: virtually all of the scenarios with a likely chance of not exceeding 2°C considered by the IPCC in their most recent climate assessment report assume that, some time around mid-century, a negative emissions technology like BECCS will be technically and economically viable and successfully scaled up (see below).[95]

Unfortunately, BECCS is currently aspirational, is unlikely ever to be technically or economically feasible, and, due to faulty assumptions about the carbon impacts of bioenergy processes, BECCS could never effectively reduce greenhouse gases from the atmosphere. In fact, massively scaled-up BECCS would worsen, not ameliorate, climate chaos.[96]

BECCS is unlikely ever to be technically or economically feasible, and, due to faulty assumptions about the carbon impacts of bioenergy processes, BECCS could never effectively reduce greenhouse gases from the atmosphere. In fact, massively scaled-up BECCS would worsen, not ameliorate, climate chaos.

BECCS requires first producing bioenergy – anything from a corn ethanol refinery to burning wood (or a mixture of coal and wood) – to generate electricity and heat. The emissions from energy production are captured and compressed to a liquid, which is injected into geological reservoirs below ground, or injected into depleted oil wells. Injecting oil reservoirs with pressurized CO_2 has been done since the 1970s to increase oil production. A recent report from the International Energy Agency describes "Advanced EOR+" as a way to "'co-exploit' two business activities:" oil recovery and CO_2 storage for profit.[97] (See Chapter 2.)

BECCS' super-status with the IPCC is based on two mistaken beliefs: 1) bioenergy itself is "carbon neutral" because the CO_2 released from bioenergy will be approximately equivalent to, and thus offset by, the CO_2 absorbed by new plant biomass growth and 2) if the CO_2 emissions from bioenergy use are captured and stored below ground, then the CO_2 absorbed by new plant biomass growth is not simply offsetting the bioenergy emissions, but represents additional carbon sequestration. So bioenergy (already presumed "carbon neutral") plus carbon storage results in a carbon negative technology

The claim that bioenergy is carbon neutral has been debated for well over a decade. A large body of peer-reviewed literature indicates that many, perhaps most, bioenergy processes result in even more CO_2 emissions than burning the fossil fuels they are meant to replace.[98] This is due to emissions from converting land into energy crop production, sometimes resulting in displacement of food production, biodiverse ecosystems or other land uses (indirect land use change); and the degradation and overharvesting of forests, increased use of fertilizers and agrochemicals, and emissions from soil disturbance, harvesting and transport, among others.

In principle, BECCS would create a substantial new carbon sink (augmenting the natural ones – oceans, soils and trees). Supporting those existing sinks, well proven across Earth's history, would make sense. BECCS, on the other hand, creates huge new demands for biomass, which only further degrades those natural sinks. BECCS boosters also trust that geological storage of CO_2, in old oil and gas reservoirs, or deep saline aquifers, will be effective and reliable.

Yet there is little real-world experience on which to base that faith. Capturing and storing carbon from bioenergy would be technically similar to the current CCS practices at a handful of fossil fuel power plants, for example:

- Cenovus Energy began injecting CO_2 from a coal-to-liquid gasification plant into the Weyburn oil field in Saskatchewan.[99] Residents became concerned after unexplained farm animal deaths and observations of bubbling and oily film on their ponds.[100] Years later, a trail of studies, both proving and disproving the leakage, leave the truth about Weyburn shrouded.[101]
- The Sleipner project in the North Sea, operated by ExxonMobil, Statoil and Total, has been injecting up to 1 million tonnes of CO_2 a year from a natural gas processing facility into a sub-seabed saline aquifer, the Utsira formation, since 1996.[102] Observations have been reported of oily water, unexplained cracking and damage to the formation related to injections,[103] an oil leak and unanticipated movement of injected CO_2 through the formation.[104] These observations are coupled with a significant discrepancy between the amount of CO_2 injected and what has been detected in seismic surveys.[105]
- A joint venture between BP, Statoil and Sonatrach in Algeria, known as the In Salah project, injected CO_2 from gas production into three wells between 2004 and 2011. A seismic study indicated that injection had activated a deep fracture zone,[106] and leakage was found from a nearby well head.[107]

Leakage, either small amounts over a long time, or an abrupt, potentially catastrophic release, would undermine any "sequestration" gains. Leaks are hard to avoid. In the US, over 3 million old oil and gas wells have been abandoned and remain unplugged,[108] and many of those penetrate the deeper formations currently in use or considered for CCS.[109] In sum, lack of reliable data on CO_2 injection (due, in part, to the fossil fuel industry's role in challenging and/or concealing results that are not favorable) make it difficult to assess safety, but it appears unlikely that geological storage can ever be considered reliable. Furthermore, monitoring for leaks would be required for decades, or even centuries. There is only one existing BECCS project in the world: the capture of CO_2 from corn fermentation at the Decatur ethanol refinery in the US, owned by ADM.[110] CO_2 is captured from the fermentation process and injected into the nearby Mount Simon Sandstone formation. This has been essentially a "proof of concept" project, funded by the Department of Energy (DOE), which claims that it provides a "carbon negative footprint." In reality, however, since the refinery is powered by fossil fuels and corn is an energy-intensive crop, declaring the project a "success" is premature.[111]

Capturing CO_2 from fermentation is less costly and complex than from other processes, and a few ethanol refineries capture and market CO_2 for use by the oil industry, where it is in high demand for enhanced oil recovery.[112] (See Chapter 2, CCS.) Flooding depleted oil wells with concentrated CO_2 results in pressure that can push remaining oil to the surface. In 2014, the US Department of Energy projected that enhanced oil recovery could triple the current proven reserves in the USA.[113] Hence there is strong lobbying, industry promotion, and market demand for concentrated CO_2. Given the high costs associated with CCS, the sale of CO_2 is essential for making carbon capture projects economically viable. Yet the injection of CO_2 to recover more fossil oil is not "climate friendly," much less "carbon negative." In fact, when used for enhanced oil recovery, according to oil industry estimates, at least a third of the injected CO_2 will be immediately released back into the atmosphere.[114] Capturing CO_2 from coal plants is complex. It has been attempted, but at great cost, and with little success:

- Canada's Saskpower Boundary Dam project, a coal plant with carbon capture which provides CO_2 for enhanced oil recovery, was among the first. It was hailed as having "exceeded expectations," but it later became clear that it was capturing only a fraction of the anticipated amount of CO_2, and using far more energy in the process.[115] Since starting operation, the facility has had numerous maintenance and other technological issues.[116] With the CO_2 provided for use in enhanced oil recovery, the emissions from this facility are even higher than they would be if the facility did not capture carbon!
- In Kemper, Mississippi, Southern Energy won millions in government subsidies and support for construction of a coal plant with CCS that was hyped as the nation's first "clean coal" facility. When construction started in 2006, the project was projected to cost $1.8 billion, but costs ballooned to over $7.5 billion and the facility was still not operational.

In June 2017, after regulators refused to allow the owners to recoup costs from customers, the plans for burning coal with CCS were abandoned and the facility is retrofitting to burn natural gas (without CCS).[117] The developers are now under investigation for fraud.[118]

- Petra Nova is another coal CCS facility in Texas. Carbon is captured post-combustion and a separate gas-fired power plant was built alongside solely to power the CO_2 capture. The CO_2 is to be used for enhanced oil recovery, enabling continued fossil fuel use. The facility began operating in a test phase in January 2017.

Capturing CO_2 from bioenergy processes such as a biomass power station, or a coal plant co-firing biomass, would be even more technically challenging and energy intensive. A unit of electricity generated in a dedicated biomass power plant results in up to 50% more CO_2 emitted than if generated from coal.[119] Since burning biomass results in higher CO_2 emissions, there is, in turn, need for yet more energy dedicated to the carbon capture process itself. This is in addition to the problems associated with securing massive quantities of biomass.

Given the lack of success with carbon capture for coal plants, and the even greater complexities and challenges associated with bioenergy (other than ethanol fermentation), it is very troubling that the esteemed IPCC embraced BECCS in their 2014 Fifth Assessment Report (AR5).[120] In that report, the IPCC assessed "Integrated Assessment Models," which were used to model trajectories for reaching various climate stabilization targets, under different policy and technology scenarios. Virtually all of the trajectories to even 2°C stabilization involved emitting more CO_2 than would be compatible with the target in the near term, and assumed that the excess could, later in the century, be somehow removed. This is the concept of "overshoot."[121] Achieving stabilization targets without overshoot were, after decades of delayed action, apparently considered too drastic, costly or impractical.

BECCS features in the IPCC report as the primary means for removing excess CO_2 later in the century (along with afforestation, though that is considered to have less potential, and even less so if forests are concurrently cut for bioenergy). The IPCC expressed both that it was "highly confident" that large scale implementation of BECCS would be required, and, at the same time, acknowledged that the technology may not be viable, carries serious risks and uncertainties and remains untested. This is a very troubling state of affairs indeed, and essentially leaves the problem of excess CO_2 in the atmosphere up to a fantasy technology, as something that future generations will need to resolve or contend with.

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The IPCC's AR5 does not refer to BECCS as "geoengineering," but rather as a mitigation technology. Either term, however, implies the use of BECCS on a scale massive enough to impact the global atmosphere. Scaling up bioenergy to that extent would have dire consequences for land use. In 2013, two environmental scientists took a sobering look at what would be required to sequester a modest 1 billion tons of carbon annually, using BECCS in a facility that burns switchgrass.[122] They reported that between 218 and 990 million hectares of land would be needed to grow the switchgrass (this is 14-65 times as much land as the US uses to grow corn for ethanol). In addition, between 17 and 79 million tons of fertilizer would be required (nearly 75% of all global nitrogen fertilizer used at present), and between 1.6 and 7.4 trillion cubic metres of water. Further, they point out that the nitrous oxide emissions from fertilizer production and use alone would wipe out any greenhouse gas benefit from CCS. More recent studies calculate that the requisite biomass would take up between 25% and 80% of current, global cropland.[123]

Land conversion on such a scale would result in severe competition with food production, depletion of freshwater resources, vastly increased demand for fertilizer and agrochemicals, loss of biodiversity, among other problems.[124] Given the technical challenges, it is unlikely BECCS would ever be scaled up enough to result in such a massive land use change. But the damage caused by false confidence and the legitimation of big bioenergy may be irreparable.

Case Study II: Fixing the climate with algae?

Because of their capacity to uptake carbon during growth, algae have become a focus of attention for "climate geoengineering" and "negative emissions." The algae approach that has taken center stage is "ocean iron fertilization" (OIF, see Case Studies III and IV), but several other algae-based climate geoengineering, CDR or mitigation approaches have been proposed.

Some advocate for using cultivated macroalgae as the source of biomass for bioenergy with carbon capture and storage (BECCS, see Case Study I, above) to provide "negative emissions."[125] Another approach would use algae cultivation as a mechanism of carbon capture and storage (CCS, sometimes referred to as carbon capture, use, and storage, CCUS). Microalgae require CO_2 for growth, and providing adequate supply can be challenging. This has led to efforts to connect algae cultivation to industrial facilities and power plants so that the flue gas CO_2 emissions are directly "fed" to the algae, which would then be processed into biofuel and other algae products (the "use" in CCUS).

A few attempts at algae CCS include: the Algoland project at Sweden's Heidelberg cement manufacturing facility;[126] Michigan State University and PHYCO2 pilot project to capture power plant CO_2 emissions;[127] a project of the University of Kentucky in conjunction with Duke Energy to capture coal plant CO_2 emissions with algae;[128] and Canada's Pond Biofuels pilot algae capture projects at St Mary's Cement facility,[129] and another at the Horizon tar sands oil facility in Alberta.[130]

An under-appreciated challenge is the process of photosynthesis itself, which limits the amount of carbon that can be absorbed by microalgae in a cultivation facility to a rate of about five grams of carbon per square meter, per day.[131] This translates into a logistical headache for projects seeking to absorb CO_2 from large industrial facilities that may spew hundreds of thousands of tons of carbon. Capturing any significant portion would require very large tracts of land located directly adjacent to the facility.

The scale of algae production that would be required to influence the global atmosphere is vastly greater than anything yet achieved in spite of decades of research and development.

A few researchers have developed theoretical scenarios for climate geoengineering by means of very large scale "ocean afforestation" – planting giant swathes of kelp or other macroalgae, similar to industrial tree plantations.[132] The algae would then be harvested and used to produce biomethane as a source of energy. They enthusiastically claim that doing so – in an area about 9% of the ocean surface area – could "completely offset anthropomorphic CO_2 emissions by 2035 and then restore the climate by reducing atmospheric CO_2 concentrations below 350 ppm by about 2085."[133] This proposal is fanciful at best, and has little serious backing.

Another algae approach involves using carbon captured by "direct air capture" (DAC, see chapter 2) to supply CO_2 required to cultivate microalgae, which can then be converted to biofuel.[134] Direct air capture has so far proven prohibitively energy intensive and costly, so the sale and "reuse" of captured carbon is considered essential. Algae are considered a promising application because they can use more-dilute CO_2, and may be more realistic than using the captured CO_2 for enhanced oil recovery.[135] [136]

The scale of algae production that would be required to influence the global atmosphere is vastly greater than anything yet achieved in spite of decades of research and development. This is due to fundamental barriers that may prove insurmountable. In spite of much hype and claims about deriving energy from algae "using nothing but water, sunlight and CO_2," the reality is that algae are tricky to cultivate en masse and require specific, energy intensive and costly conditions in order to proliferate. Cultivating algae requires access to large quantities of nutrients[137] and to concentrated CO_2. Light and temperature conditions must be carefully controlled. Some species derive energy from photosynthesis, but others require a constant supply of sugars such as sugarcane, which makes all the land use challenges associated with large-scale bioenergy monocultures relevant for algae.

Large quantities of water are needed, and the water must be constantly circulated, while water quality and pH are carefully controlled. Open ponds, or photobioreactors are generally used – both of which require access to land. Growing macroalgae on a massive scale would also require access to large areas of coastal waterways. Pests, pathogens and weather can take a major toll on algae cultivation and have proven difficult to control.[138]

Attempts to genetically engineer algae to overcome some of these barriers have been ongoing, but introduce serious risks.[139] Due to their small size and ability to become airborne, engineered microalgae will inevitably escape into the wild. Some of the traits that are being engineered are precisely those that could lend a competitive advantage in nature.

They also may prove unpalatable to the predators and grazers that normally keep natural algae populations in check.[140] Algae 'blooms' are in some cases toxic, and are increasingly common and problematic due to climate change induced warming of waterways and increased fertilizer runoff.[141] Regulatory oversight and thorough risk assessments for genetically engineered microalgae are sorely lacking.[142]

Algae are ubiquitous, diverse and play a key role as the base of food chains and source of nearly half of our oxygen. Ancient algae are a source of fossil fuel deposits and played a key role in drawing down CO_2 during a prior warming period 50 million years ago. But as an engineered climate "techno-fix," algae have so far proven uncooperative and risky.

Case Study III: Ocean fertilization: LOHAFEX, Planktos-Haida-Oceaneos

Over the last 30 years, there have been at least 13 ocean iron fertilization experiments. One of the first large experiments was the LOHAFEX expedition in 2009. Researchers on board the German vessel RV Polarstern, co-sponsored by the Indian and German governments, dumped six tons of iron sulphate over 300 square kilometres of open ocean in the Scotia Sea, east of Argentina.

The most persistent ocean fertilization advocate has been US businessman Russ George. More than ten years ago, he created a US startup company, Planktos, which by early 2007 was selling carbon offsets on its website. Planktos claimed that its initial ocean fertilization test, conducted off the coast of Hawai'i from singer Neil Young's private yacht, was taking carbon out of the atmosphere. Soon thereafter, Planktos announced plans to set sail from Florida to dump tens of thousands of pounds of iron particles over 10,000 square kilometres of international waters near the Galapagos Islands, a location chosen because, among other reasons, no government permit or oversight would be required.

In efforts to stop Planktos, civil society groups filed a formal request with the US Environmental Protection Agency to investigate Planktos's activities and to regulate its actions under the US Ocean Dumping Act.

In addition, public interest organizations asked the US Securities Exchange Commission to investigate Planktos' misleading statements to potential investors regarding the legality and purported environmental benefits of its actions. Hit with negative publicity, Planktos announced it was indefinitely postponing its plans due to a "highly effective disinformation campaign waged by anti-offset crusaders."[143] In April 2008, Planktos declared bankruptcy, sold its vessel and dismissed all employees, and claimed it had "decided to abandon any future ocean fertilization efforts."

That was not to be. Russ George reappeared a few years later, having persuaded a band council[144] of the Indigenous Haida nation on the archipelago of Haida Gwaii to fund a new project. This time, incorporated as the Haida Salmon Restoration Corporation, he pitched iron fertilization as a way to boost salmon populations, with the added benefit of selling carbon credits based on sequestering CO_2 in the ocean. In 2012, news broke that he had orchestrated a dump of 100 tons of iron sulphate in the Pacific Ocean off the west coast of Canada – the largest-ever ocean fertilization dump. An international outcry landed George with the mantle of a "rogue geoengineer"[145] and "geo-vigilante"[146] and made him the target of an investigation by Environment Canada's enforcement branch (which, five years later, has yet to conclude its efforts).

Many of those involved in this Haida project have again resurfaced, this time as the Vancouver-based Oceaneos Marine Research Foundation. Their sights now are on an experiment off the shores of Chile, where they say they are seeking permits from the Chilean government to release up to ten tonnes of iron particles as early as 2018. They have rebranded, presenting their organization as non-profit rather than for-profit; as engaging in “ocean seeding” rather than iron fertilization; and as a scrupulous project with a code of conduct and a board of scientific advisors. They have continued presenting the technology as a miracle cure to save marine life – with a much savvier online presence of scientific presentations and promotional videos showing the oceans teeming with revitalized salmon and dolphins.

Jason McNamee, who was director and operations officer of the Haida Salmon Restoration Corporation and served for some time as the chief operations officer of Oceaneos, claimed the Chilean project would not investigate its potential for carbon credits: “That’s where most of the controversy was [in 2012]. Everyone thought we were out there being cowboys hoping to make a gazillion dollars.”[147] On investigation, however, it turns out that 60% of its public IP portfolio still concerns carbon sequestration and carbon credits. Oceaneos has also promised to make all their scientific data available – the same pledge Russ George made after his ocean dump off the coast of Haida Gwaii. We’re still waiting.[148] The project has been sharply criticized by ocean scientists in Chilean research institutions.[149]

Case Study IV: Ocean fertilization: Korea Polar Research Institute

A five-year research programme (2016-2020) designed by the Korea Polar Research Institute (KOPRI) and funded by the Korean Ministry of Oceans and Fisheries, the KIFES project hopes to carry out iron fertilization experiments in the Southern Ocean. Its application for research, however, was questioned by the London Convention under its London Protocol, which bans any experiments that do not constitute legitimate scientific research.

The Korean oceanographers outlined their plan in a scientific paper published in 2016.[150] The project began with a review of past ocean fertilization experiments and a declaration of intent to move to “vessel-based research” in 2017 and 2018. KOPRI names five Korean universities and several international institutions, including US and Canadian universities, among its “domestic/international collaborative networks.” KIFES has chosen a location in the eastern Bransfield Basin, not far from the Antarctic Peninsula, for its dump.

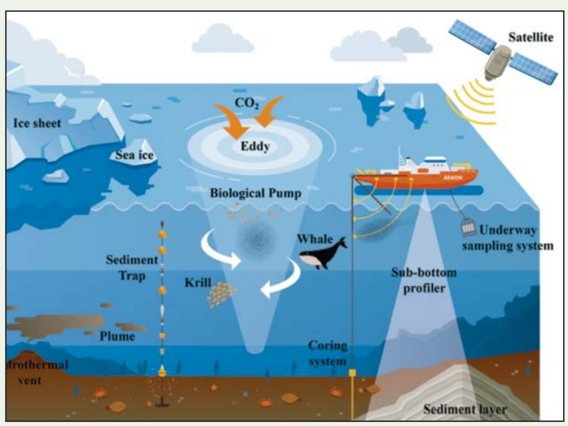

Diagram of proposed KIFES project. Illustration (cc) Yoon et al 2016 in Biogeosciences.

Building wide-spread credibility appears to be an important component of KIFES, no doubt a lesson learned from past experiments that were derailed by public outrage and protest. Before the project was questioned by the London Convention in 2017, it appears they conducted field investigations of the site. They hope to gain approval from the London Convention/Protocol in 2018, a process they say is underway, and in 2019, they hope to conduct the experiment itself and then to submit the results in 2020, before preparing the second stage of their project.

KIFES claims no interest in the selling of carbon credits – likely an implicit nod to the controversy provoked by Russ George’s commercial experiment off the west coast of Canada in 2012, a precedent not mentioned in its review of past ocean fertilization projects (see Case Study III, above). KIFES’s declared interest is in providing “a clear answer as to whether or not ocean iron fertilization is promising as a geo-engineering solution.”[151] There is no indication whether, after the questioning by the London Convention, the experiment will proceed.

Case Study V: Artificial (Ocean) Upwelling in China

China has a long history with weather modification using cloud seeding.[152] Between 2008 and 2015, China spent $1 billion on artificial weather creation and has plans to induce 60 billion cubic metres of additional rain each year by 2020.[153] Otherwise, China is a latecomer to geoengineering, but scientific interest is accelerating.

In a forthcoming essay, political scientists Kingsley Edney and Jonathan Symons suggest how and when China will become engaged in geoengineering technology development;[154] in the meantime, others have noted that, over the last three years, China's Ministry of Science and Technology invested $3 million in geoengineering research conducted by three institutions, 15 faculty members and 40 students, but this expressly excluded any development of technology or outdoor testing.[155] John Moore is a British glaciologist who serves as chief scientist of Beijing Normal University's College of Global Change and Earth System Science and oversees China's geoengineering program. He says that Chinese institutions are focusing on the potential impacts of geoengineering on polar ice sheets, sea levels, agriculture, and human health. One of the program's researchers at Zhejiang University recently co-authored a paper on "cocktail geoengineering" with Ken Caldeira, in which they modelled the impact of using two technologies in concert: the dispersion of light-scattering particles in the upper atmosphere and the thinning of high cirrus clouds.[156]

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Word of real-world experiments, however, is now starting to emerge. In 2017, China made a submission to a meeting of the London Convention in which it announced that it had conducted experiments in artificial upwelling, a form of ocean fertilization.[157] One sea trial has been conducted in the East China Sea and two in Qiandao Lake, under the auspices of the Zhejiang University.[158]

In this type of ocean fertilization, cold, nutrient-rich water from the deep ocean is pumped closer to the surface. The theory is that this changes the nutrient distribution, enhancing productivity of fish and stimulating the growth of plankton, which capture and sequester carbon dioxide when the plankton sink to the ocean floor.

Starting in 2010, the Chinese researchers have worked to develop an effective pumping system that injects compressed air through long tubes – known as an "airlift artificial upwelling system." Building off earlier devices created in Hawaii and Taiwan, the researchers have tested wave energy conversion to power the system so it can operate on its own for long periods. In a paper submitted to the London Convention, they say the most successful model they developed used a mix of photovoltaics, wind turbines, wave energy convertors, and diesel generators.[159] The experiments were conducted between 2011 and 2014, pumping water from 30 metres below the surface. In the scientists' view, the "challenges in designing and fabricating a technologically robust artificial upwelling device for structural longevity were basically overcome."[160]

The paper states that results of the experiments are yet to be submitted to scientific journals, and acknowledges that for large-scale deployment, the "uncertainties related to the potential effects on ecosystems remain unresolved."[161] Future work will focus on "measuring the environmental impacts in different coastal regions." Apart from this paper, little more is known about what was done or if and how it was assessed.

Case Study VI: The SPICE experiment

From 2010 to 2012, the UK was host to the first attempted outdoor experiment advancing stratospheric aerosol injection, which invited public attention and debate and then was cancelled before, literally, getting off the ground. Known as the Stratospheric Particle Injection for Climate Engineering – or SPICE – it was designed to test hardware for a larger-scale deployment of the technology.

The idea for SPICE was born in a "sandpit" – a short, cross-disciplinary meeting intended to generate innovative ideas – that was run by three of the UK's seven research councils.[162] Involving climate modellers, chemists and engineers, the project was backed by four universities, several government departments and private company Marshall Aerospace. The sandpit was not necessarily conducive to scientific rigour: one of the engineers involved later admitted that "we knew nothing about climate science and even less about the intricacies of dealing with highly charged social, political, ethical issues."[163]

The experiment was to test a kilometre-long hose suspended by a giant helium balloon. A pump would deliver a few dozen litres of water to the top of the hose, where it would be sprayed as a mist, evaporating before it hit the ground. It was scheduled to take place on a disused military airstrip in Norfolk, UK, in the fall of 2011.

While the experiment would likely have had no discernible effect on the environment, the ETC Group called it a "Trojan Hose" that would dangerously open the door for large-scale deployment of solar radiation management. Indeed, on SPICE's website at the time, there was a schematic of a larger hose more than 20 kilometres long, spraying a reflective aerosol much more potent than water.[164]

The "SPICE Boys," as ETC Group referred to them, appeared to some observers and even to themselves, as gleeful school-yard children playing with oversized toys. "When we all stand in that field in Norfolk, all of the engineers will be jumping up and down because they've succeeded in doing something amazing, building the tallest structure anywhere on Earth, and all of the natural scientists will be saying 'Oh shit, we're a step closer to doing something bonkers,'" a project researcher told social scientist Jack Stilgoe, who closely followed the SPICE process.[165]

This cavalier attitude was borne out in other aspects. The specifications of the technology to be tested, for instance, were arbitrary: one of the researchers acknowledged that in designing the hose's size, "we went for one, because it's a round number, and kilometre, because it's a standard unit." What they lacked in scientific method, they seemed to make up with a flair for theatre. In Stilgoe's assessment, the reasoning was "that even if the outdoor experiment did not reveal anything scientifically dramatic, it would grab public attention." Yet none of them anticipated the raucous debate that was to come.[166]

Soon after the press conference launch, the public backlash began.[167] An open letter signed by 50 organizations from around the world asked the UK Government and Research Councils to scrap the experiment.[168] Press controversy ensued. Within a week, the researchers and the research council backing them made a decision to delay the experiment.

The SPICE researchers told the media it was delayed not because of the public outrage, but a conflict of interest: they had discovered two scientists involved had not disclosed that they had submitted patents for similar technologies, before the experiment was proposed.[169] This had been communicated to the research councils, who then decided, Stilgoe says, "before they had received the letter from the NGOs." Yet it seems implausible that the public criticism was irrelevant to the decision. By April 2012, the experiment was permanently cancelled.

Across the pond, leading geoengineer David Keith was harshly critical of the SPICE project. "I personally never understood the point of that experiment," he said. "That experiment's sole goal is to find a technocratic way to make it a little cheaper to get materials into the stratosphere. And the one problem we don't have is that this is too expensive. All the problems with SRM are about who controls it and what the environmental risks are, not how much it costs. It's already cheap. So, from my point of view, I thought that was a very misguided way to start experimentation."[170] An additional concern was no doubt that the negative reactions to SPICE would threaten subsequent research and experimentation on geoengineering.

The SPICE team tried to continue their research, this time "slowed by the administrative burdens of dealing with the fallout from the proposed experiment."[171] In the end, the SPICE researchers seem to have grasped the enormity and controversy of the project they had embarked on.

One researcher admitted to Stilgoe that the experiment seemed to be "opening the gates to something else." Another SPICE scientist told him, "I totally agree with all the concerns that the public had, and we hadn't really thought about them and talked about them."[172]

Case Study VII: SCoPEx: Stratospheric aerosol injection experiment

The leader among engineers advancing solar geoengineering is Canadian David Keith, currently based at Harvard. He has been its most public face, even venturing on Stephen Colbert's talk show, where the US comedian poked serious fun at Keith's ideas. "Blanketing the Earth in sulphuric acid?" Colbert probed. "Is there any possible way that this could come back to bite us in the ass?"

Besides acting frequently as a public spokesperson, Keith has been a full-spectrum proponent: he is an investor; has lobbied governments; manages, along with Ken Caldeira, a multimillion geoengineering fund provided by Bill Gates to the Harvard University; and has commissioned a study by a US aerospace company that made the case for the feasibility of large-scale deployment of solar geoengineering technologies. In 2012, news broke that Keith and Harvard engineer James Anderson were planning the first outdoor experiment in solar geoengineering. This would have involved the release of particles into the atmosphere from a balloon flying 80,000 feet over Fort Sumner, New Mexico. Their stated aim was to measure the impacts on ozone chemistry of the release of tens or hundreds of kilograms of sulphate, and to test ways to make the aerosols the appropriate size.

The announcement came on the heels of a proposed British government-funded field test of a balloon-and-hosepipe device that would have pumped water into the sky – the Stratospheric Particle Injection for Climate Engineering (SPICE) – which was cancelled after a global outcry (see Case Study VI, above).[173, 174] Keith bemoaned its fate: "I wish they'd had a better process, because those opposed to any such experiments will see it as a victory and try to stop other experiments as well."[175]

Keith has proposed a suite of field experiments, some to test the effectiveness and risks of geoengineering and others to develop technologies for larger-scale deployment.

After media revealed Keith's own experiment, it too was cancelled, and Keith shifted energies to a new incarnation of the project. In early 2017, he helped launch Harvard's Solar Geoengineering Research Program, that aims to raise $20 million in funding by several billionaires and private foundations.[176]

Alongside other engineers and researchers, Keith has proposed a suite of field experiments, some to test the effectiveness and risks of geoengineering and others to develop technologies for larger-scale deployment.[177] The closest to execution is the stratospheric controlled perturbation experiment (SCoPEx), to be conducted in collaboration with Harvard atmospheric sciences professor Frank Keutsch. This experiment would aim to understand the microphysics of introducing particles into the stratosphere to improve estimates of the impact of solar geoengineering, including potentially dangerous ozone depletion. They first plan to spray water molecules into the stratosphere from a balloon 20 kilometres above the Earth, to create a massive icy plume to be studied from the flight balloon. They would then aim to replicate it with limestone or calcium carbonate, and sulphates – all of this to be done by 2022. This time around, Keith is covering his bases politically: he says the project is developing an independent advisory process for the experiments and trying to win broad support among civil society. This is in keeping with what appears to be geoengineers' longer-term agenda: slowly and carefully building mainstream legitimacy for large-scale experiments (that ultimately will lead to full deployment) of solar geoengineering, in the media, leading scientific bodies, and institutions of governance, both regionally and globally.

Case Study VIII: Marine Cloud Brightening in Monterey Bay, California

The theory behind cloud whitening is deceptively simple: modify the composition of marine clouds to make them whiter by spraying them with seawater. Injection of salt water theoretically increases the clouds "condensation nuclei," making them smaller and more reflective. Up to 25 percent of the world's oceans are covered with thin low-lying stratocumulus clouds (below 2,400 metres). Cloud whitening is another solar radiation management technique, and like all solar radiation management techniques, it could reduce the temperature of the atmosphere and the oceans, but would not reduce levels of greenhouse gases. Proponents imagine a fleet of unmanned vessels drawing up seawater and then spraying mist into marine clouds above.

The most prominent advocates for cloud whitening are John Latham from the National Center for Atmospheric Research at the University of Colorado and Stephen Salter from the University of Edinburgh – the latter famous for inventing the Salter Duck, a duck-shaped instrument that would bob in the ocean and theoretically convert the power of waves into useable energy (it has never been put into large-scale practice). Another proponent, Phil Rasch of the Pacific Northwest National Laboratory, has argued that based on "very artificial" models that assume "perfect cloud condensation nuclei," engineers could offset warming by three watts per square meter – so long as they seeded the clouds above with an astonishing quarter to half of the entire world's ocean.[178] The first major open-air experiment was to be overseen by a US Silicon Valley entrepreneur Kelly Wanser, who was running the Silver Lining Project in San Francisco. David Keith and Ken Caldeira steered some funding from the Bill Gates-funded FICER fund[179] to project leader Armand Neukerman, the inventor of the earliest inkjet printers who worked at Xerox Labs and Hewlett Packard. Neukerman's goal has been to develop the nozzle for ships that would fire tiny saltwater particles into the clouds, at a rate of trillions per second. The nozzle must emit particles that are small enough – 0.2 to 0.3 micrometers – to rise and remain suspended in air. In 2010, Wanser announced a large-scale experiment involving 10 ships and 10,000 square kilometres of ocean that would take place in three or four years.

But after media reported on the experiment, including the involvement of Gates in funding Neukerman's work, all traces of the project and its scientific collaborators disappeared from the Silver Lining Project's website.[180]

A few years later, the Silver Lining Project resurfaced as the Marine Cloud Brightening Project, still with Kelly Wanser as the executive director. In media coverage, they have focused on evoking a folksy collection of harmless, retired engineers tinkering in their labs instead of hitting the golf range – referring to themselves as the "Silver Linings."[181] Thomas Ackerman, a scientist at Washington University and one of the formulators of the Nuclear Winter theory, joined the project as a principal investigator.

...imagine a fleet of unmanned vessels drawing up seawater and then spraying mist into marine clouds above.

Under the aegis of the University of Washington, their first land-based field experiment is slated to take place at Moss Landing, Monterey Bay, California. They would set up nozzles on shore and spray clouds as they roll in, observing if they were whitened, while sensors on the land would assess if this led to a reduction of incoming solar radiation. They have already conducted wind-tunnel testing of a prototype nozzle in 2015 in the Bay Area, California. Reports have also emerged that Kelly Wanser is scouting to hire a public relations whiz for the Monterey experiment – clearly with the hope of not replicating the Silver Linings Project media fiasco, during which Bill Gates himself was reputed to have been upset. They plan thereafter to move experimentation to sea, propelling droplets from a small ship.[182] Initially slated for the summer of 2017, the land-based experiment has been delayed for lack of funding. The Ocean Technology Group at the University of Sydney is also proposing marine cloud brightening experiments as a way to save the Great Barrier Reef from bleaching – a proposal that Kathy Wanser has highlighted in interviews with the media.[183]

Steven Salter has also promoted the idea of cloud seeding above the Faroe Islands. The idea would be to set up nozzles on the island and spray clouds as they were heading to the Arctic, protecting it from melting. There is no indication that this experiment is moving forward.

Chapter 4

The case against geoengineering

While every geoengineering technology has its own unique problems, all geoengineering technologies share common risks and raise daunting questions of equity and justice. The problems range across ecology, society, economies and politics.

Mega Scale

For any geoengineering technique to have an impact on the global climate, it will have to be deployed on a massive scale. Unintended consequences arising from deployment could also be massive and will necessarily be transboundary.

Unreliable and high-risk

Geoengineering aims to intervene in dynamic and poorly-understood systems. Given the complexities of global climate, there are countless ways interventions could go awry, including: mechanical failure; human error; incomplete knowledge and climate data; unpredictable synergic effects; natural phenomena that may increase, decrease, or disrupt the intended effects of geoengineering (e.g., volcanic eruptions, earthquakes, tsunamis); trans-boundary impacts; change in political regimes; and funding shortfalls, among others. Trying to fix a failing geoengineering deployment could make the problem of climate change worse. No amount of precision, planning or modelling is able to accurately predict the outcome – in the short term or in perpetuity.

Environmental hazards

All proposed geoengineering techniques have potentially negative environmental impacts. For example, ocean fertilization disrupts the marine food chain, can produce harmful algae blooms and anoxia (absence of oxygen) in some sea layers.[184] Deploying bio-energy with carbon capture and storage (BECCS) implies a grab for land, water and nutrients with concomitant "massive displacements of land and people, with global implications for food supply, land rights, and environmental justice."[185]

With SRM techniques specifically, it is not possible to be certain of the effects on ecosystems' biodiversity, since it will create an entirely new ecological balance (or disturbance).[186] The energy from incoming sunlight is an essential resource for life on the planet and is closely linked, for example, to supporting the oceanic algae that produce most of the world's oxygen. Geoengineering's delusively reductionist way of dissecting the world into carbon-storing and sunlight-reflecting entities is incapable of a holistic, integrated appreciation of ecological systems, and therefore is blind to the severe damages it would inflict on ecosystems and human communities.

Irreversibility

Climate scientists often refer to irreversible climatic tipping points caused by climate change (e.g., even "negative emissions" are unlikely to be able to refreeze the Arctic). Similarly, the application of geoengineering technologies itself would also be irreversible because of the scale required, and in many cases, because of the nature of geoengineering technologies. Damage to ecosystems and people (many of which are outlined in the following paragraph) may not be undone. Once we begin artificially cooling the planet while continuing to emit greenhouse gases, we can't stop.[187] As Alan Robock explains regarding solar radiation management (SRM), "We don't know how quickly scientists and engineers could shut down a geoengineering system – or stem its effects [...]. Once we put aerosols into the atmosphere, we cannot remove them."[188] With SRM, sudden termination could lead to jumps in temperature and feedback effects that could be even more challenging than the climate effect targeted by the technology. As Raymond Pierrehumbert, University of Oxford physics professor expresses it, "if the particle injection were ever stopped, the particles would fall out in a year or so, and the world would suffer the full brunt of resurgent global warming in around a decade, a phenomenon called 'termination shock.' In other words, once you start doing albedo modification, you need to keep doing it essentially forever."[189]

Exacerbate global power imbalances and inequity

The powerful countries and corporations that are the primary emitters of current and historical GHGs are also home to the organizations and universities that are most actively investing in geoengineering research and related intellectual property.[190] These countries also dominate international environmental politics. It is widely expected, however, that the negative impacts of diverse geoengineering technologies would be particularly felt in the Global South.[191] By keeping the polluters in charge of the solution to climate change, the interests of marginalized and oppressed peoples will continue to be discounted. The prospect of controlling global temperatures raises serious questions of power and justice: Who gets to control the Earth's thermostat? Whose interests are served? Who will make the decision to deploy if such drastic measures are considered technically feasible? Governments cannot collaborate democratically to agree on a global, legally-binding climate change protocol with equitable burden-sharing. The Paris Agreement seemed to be a step in that direction, but only weeks after it had entered into force, the largest historical emitting nation (the US) withdrew. It is hard to imagine that governments will do any better when it comes to geoengineering. In fact, were we able to achieve international, sustained, democratic agreement about climate change, we would not be facing the spectre of geoengineering now.

Intergenerational injustice

The idea that geoengineering will be able to "buy time" for a change towards low-carbon policies in the coming decades is unrealistic, and places an unjust burden on future generations. For example, the theoretical efficacy and viability of "negative emissions" technologies, which do not yet exist, have already delayed urgently-needed reductions. In the (likely) event that these 'phantom technologies' fail to achieve their goal, future generations will have to deal with the consequences. Because of these risks, some climate scientists consider negative emissions technologies an "unjust and high-stakes gamble."[192] We cannot condemn our children and grandchildren to be captives of geoengineering or victims of an even harsher climate because we put our faith in future, fantasy technologies.

Justification for climate inaction

While many promoters of geoengineering maintain that the technology does not preclude urgent climate action, geoengineering provides a 'convenient' untruth for climate deniers and even governments seeking to avoid the political costs of carbon reductions. The active development of geoengineering tools and experiments enables delayed climate action and provides a justification for easing restrictions on high-carbon-emitting industries. Already some of the loudest voices calling for geoengineering research are neo-conservative thinktanks close to the fossil fuel industry who previously peddled climate denialism (such as Bjorn Lomborg's Copenhagen Consensus Center and the American Enterprise Institute).[193]

Carbon profiteering

Several geoengineers have commercial interests in geoengineering techniques. They have applied for or have been awarded patents, and some have actively sought to establish geoengineering technologies as eligible for carbon trading schemes. Competition is already stiff in the patent offices among those who think they have a planetary fix for the climate crisis. The prospect of a private monopoly holding the "rights" to modify the climate is terrifying.[194]

Convergence of large-scale emerging technologies

Geoengineering both draws on and helps proliferate other planet-altering, disruptive technologies controlled and owned by transnational corporations. For example, large afforestation schemes rely on monoculture tree plantations of genetically modified trees, and those working on "enhancing" the photosynthetic properties of crops rely on synthetic biology.[195] Massive amounts of data on the climate would be required to track removed CO_2 and incoming sunlight. Recently, geoengineers developed a specialized algorithm for their SRM deployment simulations, and concluded that algorithms were better able than humans to determine the optimal injection sites and dosages of sulfur dioxide.[196] With geoengineering, artificial intelligence, synthetic biology and Big Data converging, democratic governance of technology development will recede into the distance, while shoring up corporate interests.

Global control

Geoengineering would render the world dependent on technocratic elites, military-industrial complexes and transnational corporations to 'regulate' the global climate. Geoengineering deployment, and its perpetuation over centuries, would require the constant universal surveillance of the climate and other Earth systems. All living beings on Earth would be subjected to the imperative of storing carbon or blocking incoming sunlight, and their performance would be overseen and controlled by geoengineers. The discourse of 'climate emergency' has helped generate a doctrine of the alleged inevitability of geoengineering. This kind of "shock doctrine"[197] serves to override public concerns about geoengineering, pressing the world to acquiesce to large-scale techno-fixes with unacceptable risks and consequences. More than an attempt to solve the climate crisis, geoengineering is a grab on global power and control.

Weaponization

The historical predecessors (weather as warfare) and implications of geoengineering are often forgotten or intentionally denied.[198] The United States' clandestine cloud seeding expeditions in the Vietnam War led to the ENMOD Treaty, which prohibits the hostile use of weather.[199] Defence agencies in the United States and other countries have pondered the possibilities of weaponized weather manipulation for decades. The publicly-stated aim of geoengineering technologies is to "combat climate change," but geoengineering lends itself to dual-uses. As historian James Rodger Fleming explains, if anybody can claim to control the Earth's thermostat, the technology can and will be used for military and geopolitical advantage.[200]

Treaty violation

Deployment of geoengineering would constitute a violation of several UN treaties and decisions, including the ENMOD Treaty, the Convention on Biological Diversity and the London Convention/ Protocol.[201] Geoengineering promoters have systematically worked to undermine and delegitimize the existing intergovernmental decisions about geoengineering, instead pushing for voluntary guidelines for research, in lieu of accountable, multilateral comprehensive governance mechanisms for all aspects of geoengineering. If the attitude is to ignore the multilateral decisions and agreements that already exist, how can we expect them to respect a decision they don't like down the road?

Diversion of resources, funding and research efforts from real solutions

Geoengineering promoters argue that deploying geoengineering can be less risky than unchecked climate change. However, this is a false choice. Legitimizing geoengineering as a response to climate change undermines and distracts from the radical, system-wide changes that can effectively respond to climate change while achieving climate justice. Moreover, some geoengineering technologies will work in opposition to proven responses to climate change. For instance, SRM will reduce the effectiveness of solar cells by reducing incoming sunlight. There are urgently-needed, real, precautionary, ecological, and fair pathways for mitigation and adaptation to climate change. These include drastically reducing GHG emissions at the source; decarbonizing the global economy; and researching and supporting decentralized, affordable and fair solutions like agroecology, mass transportation, and community-owned renewable energy systems, among others. Nonetheless, there is increasingly more money being invested in geoengineering research; geoengineering is now a cross-cutting issue at the IPCC; and it has sparked diverse media and scholarly attention. Imagine if those resources were devoted to real solutions.

Geoengineering promoters argue that deploying geoengineering can be less risky than unchecked climate change. However, this is a false choice. Legitimizing geoengineering as a response to climate change undermines and distracts from the radical, system-wide changes that can effectively respond to climate change while achieving climate justice.

Chapter 5

Who is behind Geoengineering?

Old fossils, new frames

The discussions and research on intentional technological climate disruption, such as weather modification (particularly for hostile uses), can be traced several decades back, particularly to the military, including hostile deployments such as the weather modification used by the US against the Vietnamese people during the Vietnam War.[202]

In 1965, the US President's Science Advisory Committee warned, in a report called Restoring the Quality of Our Environment, that CO_2 emissions were modifying the Earth's heat balance.[203] That report, regarded as the first high-level acknowledgment of climate change, went on to recommend not emissions reductions, but a suite of geoengineering options. The authors of the report asserted, "The possibilities of deliberately bringing about countervailing climatic changes... need to be thoroughly explored." They suggested that reflective particles could be dispersed on tropical seas (at an annual cost of around $500 million), which might also inhibit hurricane formation. The Committee also speculated about using clouds to counteract warming. As James Fleming, the leading historian of weather modification, wryly noted, the first ever official report on ways to address climate change "failed to mention the most obvious option: reducing fossil fuel use."[204]

Both tracks – the desire to manipulate the climate for warfare and to avoid questioning the root causes of climate change and the fossil fuel industry – continue to be two significant underlying drivers of geoengineering research until today.

In the last decade, a new framing for climate manipulation has been developed that tries to divert public attention from the military connection, while affirming the idea that geoengineering, despite its downsides, could be a techno-fix for climate change if other paths to confront climate crisis are not politically or economically viable.

An article by the Nobel laureate Paul Crutzen in 2006, which suggested blocking sunlight by injecting sulfur particles into the stratosphere as a means to lower the temperature, was a milestone in this reframing. Not because he was the first to speak about it, but because his public image and scientific trajectory had the effect of legitimizing geoengineering.[205] Ironically, Crutzen won the Nobel Prize because of his research about the ozone layer depletion, a global environmental problem that would be worsened if sulfur aerosols were injected in the stratosphere.[206]

The Geoclique

Two of the scientists that had been reflecting on geoengineering before Crutzen were Ken Caldeira from Carnegie Institution at Stanford University and David Keith from the University of Calgary (now at Harvard).

Caldeira had worked until 2005 at the Lawrence Livermore National Laboratory, a Cold War nuclear weapons facility. There he met Lowell Wood, the inventor of the Strategic Defense Initiative (known popularly as the "Star Wars" strategy or MAD: "Mutual Assured Destruction"). Not surprisingly, Wood was a vocal enthusiast of geoengineering for all purposes, from military to climate. Although Caldeira was skeptical of many of Wood's ideas, he ended up directing his own research into geoengineering.[207]

Around that time, Keith and Caldeira were advisors to Bill Gates on climate change, and Gates became interested in geoengineering. In 2007, the billionaire started to take on his role as "the sugar daddy" of geoengineering, as journalist Oliver Morton called him.[208] With Keith and Caldeira, Gates started the Fund for Innovative Climate and Energy Research, (FICER), with money from his personal fortune given as a gift first to the University of Calgary and then Harvard University.[209]

Keith and Caldeira funded their own research on geoengineering from FICER, but also gave grants to other researchers outside their institutions. A network of geoengineering researchers started consolidating around them, in what the journalist Eli Kintisch later would call a "Geoclique."[210]

The number of researchers has increased since then, and geoengineering promoters would say it has increased notoriously. However, the number of people that lead the research, co-author publications – and also hold patents on the technologies – is still quite small and continues to be more or less the same core people in the Geoclique. This tight-knit group shows very clearly in the mapping of geoengineering that Paul Oldham et al. conducted in 2014.[211]

Cliques are not good for democracy or science

> *"Although still in its early days, the constituency for geoengineering is now developing around a network of individuals with personal, institutional and financial links. At the centre of the network is a pair of North American scientists actively engaged in geoengineering research: David Keith and Ken Caldeira."*
> – Clive Hamilton, 2013

As Clive Hamilton points out, there are many problems with this Geoclique, a kind of incestuous network of researchers with a marked US technocratic culture, that has converted themselves in the "go-to-guys" on geoengineering.

First, there are blatant conflicts of interest in declaring themselves "scientific researchers" when many of them own patents and shares in companies that would make huge profits if the technologies are adopted and deployed. They may be concerned about the planet, but they are also acting in self-interest.

For example, David Keith is the founder and owner of Carbon Engineering Ltd, a Direct Air Capture company, where Gates is also an investor. Clive Hamilton provides other examples:

> *"In addition to advising Gates and dispensing his research funds, Ken Caldeira is linked to Gates through a firm known as Intellectual Ventures, formed by former Microsoft employees and led by Nathan Myhrvold, one-time chief technology officer at Microsoft. Caldeira is listed as an 'inventor' at Intellectual Ventures. Lowell Wood, once Myhrvold's academic mentor, retired from the Lawrence Livermore National Laboratory in 2007 to team up with Intellectual Ventures. Gates is an investor. The company, whose motto is 'inventors have the power to change the world,' has developed the 'StratoShield,' a hose suspended by blimps in the sky to deliver sulfate aerosols. The device is marketed as 'a practical, low-cost way to reverse catastrophic warming of the Arctic – or the entire planet.' Intellectual Ventures has patented several geoengineering concepts, including an ocean pump for bringing cold seawater to the surface. That patent lists Caldeira, Myhrvold and Gates as inventors."*[212]

Despite the many conflicts of interest inside the Geoclique, most of them, and especially Keith and Caldeira, had prominent roles in all the reports written on geoengineering, such as the Royal Society report (2009) the NAS/NCR reports (2015) and even the privately-funded Novim Report, convened by Steve Koonin, the then-Chief Scientist at the oil company BP. This oil industry backed report also got funds from FICER.[213]

[T]he Geoclique seems to have succeeded in establishing a self-fulfilling prophecy: they produce literature that the IPCC considers when establishing that the issue exists ("there is scientific literature on the issue" says the IPCC as an excuse to consider geoengineering). Then Geoclique members become authors of the reports (who else could do it?), and finally they review each other's work.

Even more concerning, all of the Geoclique have nested at the IPCC as authors of various reports on climate change, with the support of the US and other oil-loving governments, making it difficult to add critical literature outside their own circle, as they are "the" references on the issue. Their lobby at the IPCC is particularly noticeable in the new reports that the IPCC is currently producing, such as the Special Report on 1.5 degrees, and the Sixth Assessment Report (AR6), where the IPCC seems to have taken a very biased position to favour geoengineering instead of many other possible options.

In this sense, the Geoclique seems to have succeeded in establishing a self-fulfilling prophecy: they produce literature that the IPCC considers when establishing that the issue exists ("there is scientific literature on the issue" says the IPCC as an excuse to consider geoengineering).

Then Geoclique members become authors of the reports (who else could do it?), and finally they review each other's work, all in the same circle.

A second problem is that they pretend to be experts on many other aspects than the technical ones. The Geoclique de facto claims to be experts on social, economic and political topics, including the critique of their own proposals. As Hamilton observes,

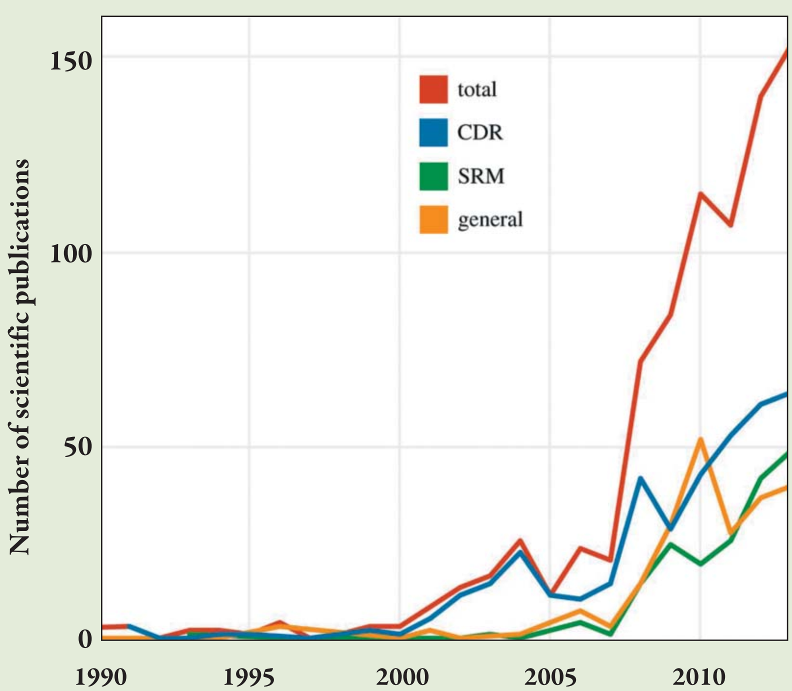
> *"In the emerging geoengineering field, scientists have assumed a privileged place in advising not merely on technical questions but on governance arrangements, ethical concerns, and international negotiations, despite their lack of expertise. The two reports of the Royal Society (the United Kingdom's National Academy of Science), along with a number of other influential reports written by groups dominated by scientists, are evidence of that."*[214]

Literature and patents – who owns geoengineering?

> *"In the absence of a governance framework for climate engineering technologies such as solar radiation management (SRM), the practices of scientific research and intellectual property acquisition can de facto shape the development of the field. It is therefore important to make visible the emerging patterns of research and patenting"*
> – Paul Oldham et al, 2014

The publications related to geoengineering have increased steadily in the last decade, but this is not because of a growing general interest in geoengineering. The publications are concentrated around some main authors – not surprisingly, all members of the Geoclique, and vast majority of WASP men[215] – whose research is largely supported by only a few funders. A clear majority of authors and funders are from the US and UK, followed by China, Russia and other European countries.

Main trends in geoengineering scientific publications



Source: P.Oldham et al. Phil. Trans. R. Soc A 2014;372:20140085

This data emerges from a bibliometric analysis done by Paul Oldham et al.[216] According to the study, the rise of literature was partly sparked by Paul Crutzen's article that proposed blocking sunlight with sulfur particles in 2006,[217] but it has particularly increased since 2008, in what the authors of the study consider a response to the debate that started at the same time both in the Convention on Biological Diversity and the London Convention, as well as within civil society.[218]

The study identified a dataset of 825 scientific publications on climate engineering between 1971 and 2013, the majority on CDR, but also a significant number on SRM proposals.

Among the institutions, the most active in publishing geoengineering research are the US National Centre for Atmospheric Research; the Max Planck Institute, Germany; Rutgers State University, US; the UK Met Office; the Carnegie Institution for Science's Department of Global Ecology at Stanford, US; and the University of Leeds, UK. Oldham's study identified 1961 authors of publications.

The majority (1343) are publishing on CDR, followed by 401 authors for SRM and 325 authors for general geoengineering. However, when they mapped the networks and clusters by issue and co-authorship, they found 20-25 authors who dominate the landscape, including Ken Caldeira, David Keith, Peter Irvine, Alan Robock, Ben Kravitz, Simone Tilmes, Olivier Boucher, Philip Rasch, Govindasamy Bala, Georgiy Stenchicov, John Latham. These authors are predominantly members of the "Geoclique," although some maintain distance and are more critical. All of them have been authors of one or more IPCC Global Assessments Report.

> *"We would emphasize that decisions on collaborations are typically made by individual researchers and reporting of collaborations may be limited. These networks are hidden from research funding organizations and hidden, beyond immediate collaborations, from researchers themselves."*
> – Oldham et al, 2014

The information on funding bodies was scarce, and the study could only find 34 percent of the sources. Based on the available data, geoengineering research funding was dominated (in order of amount of publications) by the US National Science Foundation (NSF), the UK Natural Environment Research Council (NERC), the European Commission, the US Department of Energy, the US National Aeronautics and Space Administration (NASA), and the National Natural Science Foundation of China.

The mapping of SRM funding networks showed a larger presence and tighter concentration around NSF, the European Commission and NASA. It also included private funders, through non-governmental organizations such as the Fund for Innovative Climate and Energy Research (FICER) which is funded from a gift by Bill Gates to the University of Calgary, and the Maj and Tor Nessling Foundation.

The study identified 143 patent families (first filing) related to climate engineering technologies – of which 28 were related to SRM technologies – linked to 910 patent family members. Many of them are directly or indirectly (through investors) related to members of the Geoclique.

> ***"...the climate produced by geoengineering is different to any earlier climate even if the global mean temperature of an earlier climate might be reproduced..."***
>
> Hauke Schmidt, 2012

Research on geoengineering

Most of the research is being carried in the US and Europe, where a few countries, such as the UK and Germany, play a key role. The style of research tends to be quite different between European and US researchers – European research projects are generally more cautious and give more attention to environmental impacts, social participation and lack of governance. We present here the main geoengineering research projects.

Multinational research projects

IMPLICC

The Implications and Risks of Engineering Solar Radiation to Limit Climate Change (IMPLICC) Project is an EU-funded project that was carried out from July 2009 to September 2012 by five research and academic institutions in France, Germany and Norway. The activities were coordinated by the Max Planck Institute for Meteorology in Hamburg.[219]

The project made computer models of impacts with three SRM techniques (stratospheric aerosol injection, space mirrors and marine cloud brightening) and used two different scenarios from those discussed at the IPCC.

Under the scenario of a quadrupling of CO_2 in 2100 (the "business as usual" scenario), rainfall strongly decreases – by about 15 percent of preindustrial precipitation values – in large areas of North America and northern Eurasia. Over central South America, all models show a decrease in rainfall that reaches more than 20 percent in parts of the Amazon region. Other tropical regions see similar changes, both negative and positive. Overall, global rainfall is reduced by about five percent on average in all four models studied. "The impacts of these changes are yet to be addressed, but the main message is that the climate produced by geoengineering is different to any earlier climate even if the global mean temperature of an earlier climate might be reproduced," said Hauke Schmidt, the lead author of the paper published with the results.[220] IMPLICC also made scenarios for the economic impact of geoengineering, and concluded that in most scenarios, geoengineering would have a negative economic impact with decreased gross domestic product in several regions, particularly Asia.[221]

They also noted that there is a high degree of uncertainty concerning the implications of climate engineering because of the limited understanding of climate processes in general. For example, the manipulation of marine clouds is based on aerosol-cloud interaction processes which are, according to IMPLICC, a "big open question" of climate research. Likewise, injecting sulfur into the stratosphere would not only have radiative but also dynamical effects that are poorly understood. The conclusions also noted that political, ethical, legal and further economic implications must be considered and that based on the results of their models, it seemed clear that geoengineering cannot be seen as a substitute for mitigating climate change through the reduction of greenhouse gas emissions.[222]

EuTRACE

The European Transdisciplinary Assessment of Climate Engineering (EuTRACE) is an EU-funded project carried out from 2012-2015 that brought together 14 academic and research institutions from Germany, the UK, France, Austria and Norway.[223]

The main project deliverable is a report that assesses the potentials, risks and uncertainties of geoengineering technologies within the context of discussions on climate change, mitigation and adaptation. The report focuses on bio-energy with carbon capture and storage (BECCS), ocean iron fertilisation (OIF), and stratospheric aerosol injection (SAI).

Among the main conclusions of the EuTRACE report is the statement,

> *"In general, it is not yet clear whether it would be possible to develop and scale up any proposed climate engineering technique to the extent that it could be implemented to significantly reduce climate change. Furthermore, it is unclear whether the costs and impacts on societies and the environment associated with individual techniques would be considered acceptable in exchange for a reduction of global warming and its impacts, and how such acceptability or unacceptability could be established democratically."*

On the technical aspects of the technologies, they conclude that geoengineering technologies "face numerous scientific and technical challenges," including technical and economic feasibility which are not proven, and,

> *"much deeper understanding of the underlying physical processes, such as [e.g] the microphysics of particles and clouds, as well as how modification of these would affect the climate on a global and regional basis [...] A further challenge that generally applies to both greenhouse gas removal and albedo modification is that their application could result in numerous technique-specific harmful impacts on ecosystems and the environment, many of which are presently uncertain or unknown."*

On the social context, the report express concerns, among others, about the "moral hazard":

> *"[...] the concern that research on climate engineering would discourage the overall efforts to reduce or avoid emissions of greenhouse gases; [...] the impact of various climate engineering techniques on human security, conflicts and societal stability; [...] the justice considerations, including the distribution of benefits and costs, procedural justice for democratic decision making, and compensation for harms imposed on some regions by measures that benefit others."*

On governance, they state that, "[at] present, no existing international treaty body is in a position to broadly regulate greenhouse gas removal, albedo modification, or climate engineering in its entirety. The development of such a dedicated, overarching treaty (or treaties) for this purpose would presently be a prohibitively large undertaking, if at all realizable."

They suggest for the time being to consider the "discussions and passed resolutions" of the CBD and the London Convention/London Protocol, and that the EU could try to have a collaboration among these and the UNFCCC to develop common position on various techniques and general aspects of climate engineering, based on "the precautionary approach, the minimization of harm, the principle of transparency, the principle of international cooperation and research as public good."

International Geoengineering Model Intercomparison Project (GeoMIP)

The Geoengineering Model Intercomparison Project (GeoMIP) is a broad international research project that uses different computer climate models to see the response of climate to different solar geoengineering techniques.[224] The project was founded by Alan Robock and Ben Kravitz in 2010, and has done several rounds of comparisons with some 50 papers published. GeoMIP studies have been important to recognize the most probable impacts of SRM techniques, e.g., the unequal effects on different regions of the world, such as the severe effect on the Monsoon in Asia and drought in Africa. As the name indicates, GeoMIP compares the results of various models, giving a better understanding of both the coincidences of the models and the differences between them, showing where there are large uncertainties.

ETC Group has done regional fact sheets based on results of the GeoMIP, highlighting the impacts of SRM in Asia, Africa and Latin America.[225] In 2015, a sister project to GeoMIP was initiated to look at the effects of CDR techniques: CDR-MIP.[226]

National programs

China: Mechanism and Impacts of Geoengineering

This is a federally-funded Chinese research project, supported by the National Key Basic Research Program of China, under the Ministry of Science and Technology, with an approximately US $3 million budget.[227]

The project started 2014 and has three areas of work:

1) Understanding the physical mechanisms of geoengineering and scheme designs;
2) Assessing the climate impact of geoengineering by analyzing existing and ongoing GeoMIP simulation results; and
3) Evaluating the impact, risk, and governance of geoengineering.

It is a collaboration among four Chinese research and academic institutions. It has 15 faculty members and 40 students, led by Professor John Moore at Beijing Normal University.[228] The effort explicitly does not include technology development or outdoor experiments.[229]

The number of researchers involved make it the largest geoengineering research program in the world, but it is relatively small in Chinese terms.

European national programs

Beyond the multinational research collaborations, there have also been European geoengineering programs at the national level. These have been conducted by universities and research institutions such as the UK Research Council-funded Integrated Assessment of Geoengineering Proposals (IAGP, 2010-2015) and the Stratospheric Particle Injection for Climate Engineering (SPICE, 2010-2013), the Norwegian EXPECT project (2014-2016) and the German Research Foundation (DFG) Priority Programme on Climate Engineering (2013-2019), coordinated by the Kiel Earth Institute with 17 participating German research and academic institutions.

In April 2017, an £8.6 million UK research programme on greenhouse gas removal was initiated, jointly funded by the Natural Environment Research Council (NERC), the Economic & Social Research Council (ESRC), the Engineering and Physical Sciences Research Council (EPSRC) and the Department for Business, Energy and Industrial Strategy (BEIS).[230]

US national programs

In the US, the National Academy of Sciences and the National Research Council produced two long reports on geoengineering in 2015, one focused on CDR and another on SRM.[231]

There are geoengineering research programs at the US National Center for Atmospheric Research, the Pacific Northwest National Laboratory, the Carnegie Institution for Sciences, Cornell University, University of Washington and Rutgers University, among others.

In April 2017, David Keith opened Harvard's Solar Geoengineering Program, financed by several private foundations and personal donations by Bill Gates and other philanthropists.[232]

In contrast to the European and Chinese programs, the US programs aim to undertake outdoor experiments. Particularly, Keith's Harvard program announced the intention to make an SRM field experiment in 2018 (SCoPEx, see Chapter 3, Case Study VII). In November 2017, under the Trump administration, the US had a Congressional Hearing on geoengineering, potentially signaling the intention to develop a national research program.[233]

The IPCC: normalizing geoengineering?

The Intergovernmental Panel on Climate Change (IPCC) has not discussed geoengineering at length until recently. It made minor mentions of geoengineering in its Second, Third and Fourth Assessment Reports, indicating, for example, that "geoengineering options are largely speculative and unproven and with the risk of unknown side-effects."

In recent years, the IPCC seems to have been chosen by the pro-geoengineering lobby as one of the main points of entry for the "normalization of geoengineering" at the international level – a place where geoengineering can be included as just "another option" along with mitigation and adaptation to climate change.

In 2011, the IPCC held a Meeting of Experts on Geoengineering, an initiative that was widely criticized by 160 international and national civil society organizations. One of the critiques was that the IPCC, as an advisory scientific panel, should not discuss governance, which is about political decisions, not techniques.[234]

Another factor that is gaining traction in the argument for considering geoengineering techniques, particularly GGR/CDR, is that the IPCC reports that the residual effect of some of the GHGs already emitted, particularly CO_2, will last in the atmosphere for long periods of time, so even if there would be deep emissions cuts immediately the greenhouse effect would continue. Because of this, there is an increasing number of scientists and governments that seem to think that it is "inevitable" to use some kind of CDR techniques to remove the excess CO_2 from the atmosphere. There are several concerns related to this position.

Although the climate situation is undoubtedly serious, the assumptions in the models used by scientists referred to in IPCC are based on series of parameters (physical, climatic, economic) that are estimates.

The bases for the models are changeable, according to new science, or according to which science is considered. In the IPCC, some of the underlying models, e.g. climatic models, have changed from one Assessment Report to next one while the economic models remained mostly static. The models neglect certain variables and interactions and enhance others – they are therefore not to be regarded as fixed realities.

Furthermore, even if the effects of the emitted gases will have long term impacts on the climate, there are several other possibilities to reabsorb part of the excess gases other than geoengineering techniques, such as careful natural ecosystem restoration and agroecological agriculture, among others, that are not being considered by the IPCC.

In their Fifth Assessment Report (AR5), released in 2014, the IPCC included smaller sections analyzing some of the CDR techniques and in its Synthesis Report expressed that:

> *"SRM technologies raise questions about costs, risks, governance and ethical implications of development and deployment. There are special challenges emerging for international institutions and mechanisms that could coordinate research and possibly restrain testing and deployment. Even if SRM would reduce human-made global temperature increase, it would imply spatial and temporal redistributions of risks. SRM thus introduces important questions of intragenerational and intergenerational justice. Research on SRM, as well as its eventual deployment, has been subject to ethical objections. In spite of the estimated low potential costs of some SRM deployment technologies, they will not necessarily pass a benefit–cost test that takes account of the range of risks and side effects. The governance implications of SRM are particularly challenging, especially as unilateral action might lead to significant effects and costs for others."*[235]

Notwithstanding, and despite the lack of knowledge about the impacts of the unproven technology, the IPCC considered the extensive use of one geoengineering approach in AR5: bioenergy with carbon capture and storage (BECCS), which was used in the majority of the scenarios for possible futures. In the Representative Concentration Pathways (RCPs) offered to climate policy makers, the use of BECCS and "negative emissions technologies" were heavily represented, without any consideration of their viability and the extremely serious social, food security and environmental impacts that the large deployment of BECCS would imply. This bias motivated the publication of an increasing number of highly critical papers from both scientific media and civil society organizations.[236]

Notwithstanding, in the approved outline for AR6 (due in 2021), geoengineering, separated as GGR and SRM proposals, appears frequently in the work of the IPCC. It primarily features in Working Group III, which discusses mitigation options, and shows up in Working Group I, which discusses the science of climate. In Working Group I, the presence of geoengineering is illogical: geoengineering is not a science – rather, it is a series of theoretical speculative proposals based on mathematical computer models, for which the bases are changing all the time, because the dynamic complexity of the climate system and climate change grossly exceed what models can capture without uncertainties. It is even more unusual for Working Group I to take these technologies into consideration when they do not consider any other alternatives proposals for addressing climate change – either existing or proposed. These inconsistencies reveal a biased selection towards proposals and literature on geoengineering.

Working Group III will also contain a special chapter on “cross-sectoral” perspectives that will include geoengineering techniques not covered in other chapters. Geoengineering is also included as one of eight cross-cutting issues for all Working Groups (I, II and III), and will have a specific section devoted to it.

While AR5 had an excessive and scientifically unjustified reliance on BECCS and afforestation, AR6 is going to fully embrace the discussion of nearly all geoengineering technologies available – their status, cost, risks and impacts, but also their potential.

One big problem, as described in earlier in this chapter, is that the vast majority of geoengineering authors, critics and reviewers are all in the same circle of geoengineering researchers – the discussion is dangerously self-referenced and disregards the critical views from civil society and governments as well as the alternatives that are not in the frame of geoengineering.

Another area of concern is the presence in some IPCC reports of authors that are employees of the oil industry, something that for civil society is a clear conflict of interest.[237] This adds to the fact that the current IPCC Chair is a former ExxonMobil employee who has publicly expressed that geoengineering should be considered.[238]

The Climate Merchants

The political economy of geoengineering, while still under-developed and contested, is beginning to generate a momentum of its own. Commercial interest is creating the outlines of a faction of actors with an economic self-interest in more research, and eventually deployment. This faction could become a more organized commercial lobby that puts increasing pressure on governments and international bodies of governance.

To date, geoengineering remains too controversial for most big corporate investors, with fossil fuel and automobile industries much more likely to fund market-friendly options and organizations than they are to openly advocate for geoengineering solutions. Billionaire philanthropists are sprinkling large sums of money, small companies are pursuing it commercially, and some big companies are beginning to quietly fund research while also trying to impact policy.

Billionaires with a self-styled passion for saving the world – while making some money on the side – have begun encouraging geoengineering. Richard Branson, CEO of Virgin Airlines, offered $25 million for a climate techno-fix as part of his “Virgin Earth Challenge.”[239] He has also devoted considerable resources to the Carbon War Room, a “geoengineering battlefield,” and has promoted “carbon negative” proposals like DAC and BECCS and has engaged in obtaining offsets for biochar and cloud whitening. Branson has been very bullish on the technology, having been quoted saying, “if we could come up with a geoengineering answer to this problem, then Copenhagen wouldn’t be necessary. We could carry on flying our planes and driving our cars.”[240]

Bill Gates has provided $8.5 million to scientists David Keith and Ken Caldeira for geoengineering and climate-related research.[241] Microsoft’s former technology chief, Nathan Myhrvold, has patented geoengineering technologies through his company Intellectual Ventures, including the StratoShield, a hose tethered to a balloon in the sky that would disperse sulphate aerosols.[242] Both Gates (through the FICER fund) and Branson (through the Carbon War Room) have provided funding to the so-called Solar Radiation Management Governance Initiative, headed up by the UK Royal Society.[243]

Then there are large companies for whom saving the world – exclusively through some sort of techno-fix – is increasingly becoming a structural prerequisite to continuing their insatiable search for profits. They have not been so publicly visible on geoengineering.

Their role has instead involved trying to shift policy norms so that previously unthinkable notions and activities – like emissions overshoot, net zero emission targets, and solar radiation management – start to become more mainstream and acceptable.

Among the larger companies, Big Oil predominates. ExxonMobil's Senior Scientific Advisor Haroon Kheshgi is their point person on geoengineering, recruited from the Lawrence Livermore National Laboratory.[244] He was the first to propose liming the oceans to reduce acidification based on ExxonMobil-funded research.[245] Through his efforts, Exxon has influenced "independent" reports on geoengineering and has funded a report advocating for SRM. ExxonMobil's former CEO, and now US Secretary of State, Rex Tillerson has described climate change as an "engineering problem" with "engineering solutions."[246]

For its part, Shell has been involved in the International Biochar Initiative and funded a small geoengineering startup called Cquestrate, which was a project of Tim Kruger, who now manages The Oxford Geoengineering Project.[247] Their chief Lobbyist – David Hone – is one of the most evangelical about "negative emissions" and increasingly supports SRM.[248] When Steve Koonin was chief scientist at BP, he led a project at the newly-formed Novim group – which he initiated – to determine hardware feasibility for SRM experiments (although this may have been more in a military than industrial capacity).[249] Boeing's Integrated Defence Systems Chief Scientist and Vice-President David Whelan (formerly of DARPA) is also active in debates, claiming there is a small team at Boeing studying the issue.

He has publicly mused about the technical feasibility of getting mega-tonnes of aerosol sulphates up to different stratospheric levels via aircraft or large cannons.[250] Conoco Philipps Canada, which invests in the Alberta tar sands, was the first oil company to get involved in backing "industry-led" protocols for biochar for the Alberta Offsets System.[251] Expanding biochar research has since been funded by ExxonMobil, Chevron and Encana, and Cenovus is planning a tar sands "waste-to-biochar" reclamation project, co-owned by Conoco Philipps.[252]

Billionaires with a self-styled passion for saving the world – while making some money on the side – have begun encouraging geoengineering.

These actors are joined by several smaller companies whose business plans are built around geoengineering. They have pursued opportunities in ocean fertilization, BECCS or Direct Air Capture, plus a few other semi-commercial, small startup projects in other technologies. Many of them have sought carbon credits, though there is little possibility that such activities will be recognized soon in any emissions trading systems. The most persistent of these companies is the ocean-fertilizing Planktos, which transmuted into the Haida Salmon Restoration Corporation and now Oceaneos, acting in Chile. For a short while, Climos existed as a commercial ocean fertilization firm founded by Dan Whaley, who was formerly a Planktos employee, but it now appears non-operational. Ocean Nourishment Corporation is another commercial ocean fertilization company, based in Australia and headed by Ian SF Jones. They appear to be in business, although not active. He has taken out patents that claim, astonishingly, to own any fish nurtured through ocean fertilization.[253] Another company called Atmocean had developed means to bring nutrient rich seawater up to the sea surface (so-called ocean mixing technology), but seems to have moved on to other non-geoengineering projects.[254]

The most commercially active geoengineering technology is Direct Air Capture (DAC). David Keith's company Carbon Engineering is funded by private investors including Bill Gates and Murray Edwards, the billionaire tar sands magnate who runs Canadian Natural Resources Ltd. They opened an $8 million pilot plant in Squamish, British Columbia, in 2015, where they claim to extract about a tonne of carbon dioxide a day.[255] Swiss company Climeworks, founded by engineers Christoph Gebald and Jan Wurzbacher, say they have created the "first commercial plant to capture CO_2 from air," in a canton of Zurich.[256]

They claim the $23 million plant is supplying 900 tonnes of CO_2 annually to a nearby greenhouse to help grow vegetables. They have a partnership with automobile company Audi. Other companies include Global Thermostat, bankrolled by Goldman Sachs and partnered with Algae Systems,[257] as well as Skytree in the Netherlands and Infinitree (formerly Kilimanjaro) in the US.[258]

David Keith and other developers have pitched DAC as a means to use captured CO_2 to massively scale up enhanced oil recovery (EOR) industry in the US and elsewhere. At a DAC summit in Calgary in 2012 there were a number of oil companies in attendance – including Suncor, BP, Husky Oil, and Nexen – scouting the prospects. Keith, who owns the patent for the carbon-sucking "Planetary Cooler," has said that if the right conditions emerge, "we're printing money."[259] However, his optimism for a business case for DAC is belied by the reality that it is not economically feasible: it remains much cheaper to capture CO_2 from the flue gas of a coal power plant, for instance, than from ambient air.[260] Moreover, using carbon sucking machines to enable EOR would nix any supposed climate mitigation benefits: the latter will generate more CO_2 than the former captures.[261] DAC technology has also attracted the attention of venture capitalists like Ned David, who is keen on EOR and also runs an algae synthetic biology company. He hopes to create biofuels by feeding captured carbon to algae produced in giant vats outdoors in Nevada, and has sought funding from Monsanto.[262] Because of the huge demand of energy that DAC implies, some geoengineering promoters have proposed to use "small nuclear power plants" connected to DAC installations.[263]

In solar radiation management, a private company called Silver Lining was run by Silicon Valley tech entrepreneur Kelly Wanser, but has recently rebranded as noncommercial and partnered with the University of Washington scientist Thomas Ackerman.

Observers have seen an uptick in geoengineering patents in recent years and warn that the patents owned by private companies and individuals risk becoming, as Clive Hamilton notes, the "de facto form of governance of geoengineering."[264]

War climate: military & geoengineering

Military interest in geoengineering has a murky history, but tracing its visible contours reveals a steady, disturbing creep of military involvement. Journalist Jeff Goodell, who is sympathetic to geoengineering, calls the military connection the elephant in the room: "It's not easy to see how a serious geoengineering program could move forward without some degree of military involvement both here in the United States and in countries such as China and Russia."[265]

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Weather control has long been a consideration of military strategists. A widely-quoted 1996 paper commissioned by the US Air Force suggested that weather modification is potentially a "force multiplier with tremendous power that could be exploited across the full spectrum of war-fighting environments." By 2025, it suggested that the US could "own the weather." A later report urged consideration of geoengineering options.[266]

Science historian James Fleming refers to the "long paper trail of climate and weather modification studies by the Pentagon and other governmental agencies."[267] In his view, "geoscientists with high-level security clearances share associations, values, and interests with national security elites." No less than the "father of the atom bomb" Edward Teller was involved in early discussions of geoengineering, as was his protégé, Star Wars architect Lowell Wood – who has declared that large-scale geoengineering deployment is "written in the stars."[268]

As increasing attention is paid by the military to the "security" implications of climate change, we may see this connection become a veritable military-geoengineering complex.

Many of the most active members of the Geoclique have ties to the Lawrence Livermore National Laboratory or the Pentagon's DARPA (Defense Advanced Research Projects Agency), both of which have deep military mandates, budgets and contracts. DARPA's aim is to "maintain the technological superiority of the US military." In 2009, it hosted their first known geoengineering meeting.[269]

Soon after, a new non-profit scientific corporation called Novim Group was launched. It was shepherded by Steven Koonin, chief scientist at BP, later to be appointed Under-Secretary for Science at the US Department of Energy under Obama. Koonin is a member of JASON, a secretive group of scientists who advise the US military and put out special reports, half of which are confidential, half public. Novim soon released an influential public study on deploying solar radiation management as a response to "climate emergencies."[270] Surprisingly, half the authors of the study were part of JASON – suggesting that, in authorship and intent, it had all the hallmarks of being a military report.

In 2011, the RAND Corporation, a think tank with long-term ties to the US military, followed up with the publication of an analysis of geoengineering options in which it encouraged the US government to establish international norms to govern geoengineering research.[271] More recently, the CIA funded a National Academy of Sciences study on geoengineering, the first NAS study to be supported by an intelligence agency.[272]

In April 2017, Steve Koonin (again), now as academic at New York University, wrote an op-ed for the Wall Street Journal[273] proposing a "red team" of dissenting scientists to critique major scientific reports on climate change and a "blue team" of climate scientists to rebut the criticisms, resulting in a public back-and-forth."[274] A few months after, the US Environmental Protection Agency echoed Koonin, calling for the same.[275]

Although this effort could seem to be a general discussion around climate change denial and rebuttals, the active involvement of Koonin seems to indicate that promoting a program on geoengineering – with potential military and oil industry backing – could be on the horizon. The bottom line rationale would be, in this case, the close link between climate deniers and geoengineering: they don't agree on who caused climate change, but they can agree on engineering and technological "solutions" to any problem caused by climate change, regardless of who caused it.[276]

A consequence of developing such a program could be the intensification of geoengineering programs in Russia and China, among others, for geopolitical and military reasons.

"If, as history shows, fantasies of weather and climate control have chiefly served commercial and military interests, why should we expect the future to be different?"

James Fleming, 2010

As James Fleming has shown, the military distorts science and engineering by imposing secrecy on new discoveries and seeking to weaponize every technique, even those designed for peaceful purposes. In exchange, they offer scientists access to political power, an unlimited stream of resources, and the ability to deliver on the promise of controlling nature, weather, or the climate.[277] Indeed, some geoengineering scientists like Gregory Benford have argued the military must be involved, as they "can muster resources and they don't have to sit in Congress and answer questions about every dime of their money."[278]

Fleming concludes his study of the historical connection between the military and geoengineering with a sense of foreboding: "If, as history shows, fantasies of weather and climate control have chiefly served commercial and military interests, why should we expect the future to be different?"[279]

Conservationist for the Earth... Manipulation

Most environmental groups that are aware of geoengineering are highly critical, believing passionately that energy should be focused instead on real solutions to the root causes of climate change. But among those who identify as environmentalists, there are a few environmental NGOs who are skeptical but open to research, and others in the eco-modernist tradition who believe technologies like geoengineering can be harnessed for the sake of humanity.

Environmental Defense Fund (EDF) is one of the three conveners of the Solar Radiation Management Governance Initiative, and supports "transparent small-scale field research" of SRM and "research on development of carbon dioxide removal techniques." Gernot Wagner, who with David Keith co-founded Harvard's new Solar Geoengineering Program, previously worked in EDF's Office of Economic Policy and Analysis. The Natural Resources Defense Council has also said it is "prudent" to support such research, and WWF-UK has come out in cautious support of "research into geoengineering approaches in order to find out what is possible."[280]

Those more fully enthusiastic include eco-modernists like Stuart Brand, the author of Whole Earth Catalog, who thinks there should be a "full court press" on geoengineering technologies.[281] The Breakthrough Institute, a think tank in Oakland, California founded by Michael Shellenberger and Ted Nordhaus, actively promotes geoengineering solutions.[282]

The Arctic Methane Emergency Group – a group of older scientists who made a futile intervention at the Cochabamba climate conference in 2009 – urges deployment of geoengineering technologies as soon as possible to "refreeze the Arctic." And Gaia theorist James Lovelock has also suggested geoengineering should be thought of as "planetary medicine."[283]

Defending Mother Earth: geoengineering and indigenous resistance

As an approach that treats the living globe as an engineerable subject and whose strongest proponents are transnational actors, it is no surprise that some of the most trenchant critiques of geoengineering have come from Indigenous Peoples and their movements, who espouse a place-based and more sacred relationship with Mother Earth. The very idea of geoengineering re-casts the global climate and other Earth systems as mechanistic processes that can be pragmatically altered with a herculean science project. In classical mythology, Hercules' strongest foe was Antaeus, the land-hugging giant who drew his strength from being in touch with his mother, the Earth. Like Antaeus, indigenous movements worldwide are increasingly setting the front lines of resistance to herculean fossil fuel and extractive projects, citing the rights of Mother Earth and sacred defence of land and water. Resisting geoengineering is emerging as part of that struggle.

In 2010, the World's Peoples Conference on Climate Change and the Rights of Mother Earth in Cochabamba, Bolivia, gathered more than 35,000 mostly indigenous participants and issued a Peoples' Agreement of Cochabamba that explicitly rejected geoengineering as a "false solution" to the climate crisis.[284]

Also launched in Cochabamba was a 'Hands Off Mother Earth' (HOME) campaign against geoengineering tests. At the launch of the HOME campaign, Ben Powless of the Mohawk Nation (Canada), representing the Indigenous Environmental Network, explained:

"For too long our peoples' bodies and lands have been used to test new technologies. Now, in response to climate change, these same people want to put Mother Earth at risk with geoengineering technologies. We can't afford to threaten our planet in this way, especially when simple, just and proven solutions are at hand."

It was not the first time indigenous movements had spoken out on geoengineering. A year earlier, the Indigenous Peoples Global Summit of Climate Change meeting in Anchorage, Alaska, had issued a clear challenge to States "to abandon false solutions to climate change that negatively impact Indigenous Peoples' rights, lands, air, oceans, forests, territories and waters (...) including geoengineering."[285]

These statements and others like them must be understood in the context of several subsequent geoengineering schemes targeting indigenous lands and waters. In 2007, Planktos Inc had planned to carry out ocean fertilization around the Galapagos affecting traditional fishing grounds, and in 2008 Ocean Nourishment Corporation of Australia had intended to release urea in the Sulu Sea in South East Asia, home to several indigenous groups who were not consulted.

Most high profile was the case of the Haida Salmon Restoration Corporation (HSRC) – a geoengineering firm founded by long-time geoengineer Russ George and staffed almost entirely by non-indigenous scientists but presented to the world as an indigenous project supported by the Haida community of Old Masset on Haida Gwaii, Canada.

Indigenous Environmental Network and Confederacion de Naciones Indigenas del Ecuador in Cochabamba, Bolivia, 2010. Photo (cc) Jeff Conant

Indeed, when it became clear that HSRC had not complied with Canadian law, the principals of the corporation even turned to Haida Sovereignty claims in their defence and flew a Haida flag (rather than a Canadian flag) while they were dumping iron at sea.

This geoengineering project created significant rifts within the Haida indigenous community on the islands of Haida Gwaii, even to the extent that an intra-island basketball tournament was boycotted in protest.

"The consequences of tampering with nature at this scale are not predictable and pose unacceptable risks to the marine environment. Our people along with the rest of humanity depend on the oceans and cannot leave the fate of the oceans to the whim of the few."

Guujaw, president of the Haida Nation, 2008

However, the hereditary Council of Chiefs and the Haida Nation issued a clear rejection of the geoengineering scheme, signed by Guujaw, the president of the Haida Nation, clarifying that the actions of HSRC did not reflect those of the Haida Nation. "The consequences of tampering with nature at this scale are not predictable and pose unacceptable risks to the marine environment. Our people along with the rest of humanity depend on the oceans and cannot leave the fate of the oceans to the whim of the few."[286]

Chapter 6

Geoengineering Governance

Is it possible to govern geoengineering?

When speaking about geoengineering governance, a sensible first question is whether geoengineering, with its inherently high risks, unequal impacts, long term effects and broad geopolitical, military, environmental and global justice implications, is even possible to "govern."[287]

Particularly, the deployment of Solar Radiation Management (SRM) poses potentially unresolvable governance issues, including potential irreversibility and that its deployment could endanger the food and water sources of billions of people in Asia and Africa in a transboundary manner. But all proposed geoengineering schemes, if deployed at the spatial scale and time scale necessary to influence the climate, will involve grave and unfairly distributed negative impacts.

The question of whether it is even possible to govern geoengineering is valid and urgent. However, governance is not only about establishing regulations to legalize and permit the development of a certain technology. Banning the use of a too-risky technology is also an approach to governance, as is the case with the Nuclear Test Ban Treaty[288] and the UN's adoption of a Treaty to Prohibit Nuclear Weapons, Leading Towards their Total Elimination, in July 2017.[289] Nuclear testing had devastating impacts on some regions and Indigenous Peoples. In the case of geoengineering, we can avoid the same mistake by developing strong, precautionary multi-lateral governance of geoengineering in advance, commensurate with its risks.

The question of whether it is even possible to govern geoengineering is valid and urgent. However, governance is not only about establishing regulations to legalize and permit the development of a certain technology. Banning the use of a too-risky technology is also an approach to governance.

"Governing geoengineering" is not just a future governance outcome, but pivots on the process leading up to it. The current debates on geoengineering (and its governance structure) often privilege technocratic worldviews and engineering perspectives, as well as vested interests, from pro-geoengineering academic researchers (who may in some instances also have economic stakes in the issue), the fossil fuel industry and others with clear economic or geopolitical interest in the proposals. Together, these voices dominate the conversation. Such an unbalanced process leads towards biased, undemocratic governance outcomes.

It also pre-empts the fundamental question of whether we need geoengineering to confront climate change or whether there are other, much safer alternatives we should affirm, promote, develop and apply political will towards first.

The Holy Grail of "negative emissions"

In 2015, the Paris Agreement on climate change agreed to limit the increase of the global temperature to "well below 2 degrees," including to "pursue efforts to limit the increase to 1.5°C above pre-industrial levels" before the end of this century. But the sum of the nationally determined contributions (NDC) delivered by each country to UNFCCC one year later translated into a global average increase of 2.9-3.4 degrees celsius.[290] This gap is a grave concern that must be addressed by immediate and real emission cuts, along with a fundamental change of the energy matrix and industrial production and consumption patterns, starting with the few countries that are responsible for more than two thirds of the global GHG emissions.

But instead of advancing these necessary measures, the concept of "negative emissions" – the idea that it is possible to generate energy in a manner that removes GHG from the atmosphere, or that emissions can be offset by technological (or other) means, thus avoiding drastic GHG emissions cuts, has gained traction.

This notion of a techno-fix for getting to 1.5 degrees paved the way for geoengineering boosters to scale up their discourse and present geoengineering proposals not as a reserve or an emergency plan, but as an "unavoidable" measure to be taken sooner rather than later. They have also used this argument to demand more public and private support for their research and experiments.[291]

The moral dilemma of the techno-fix route is that since none of the geoengineering techniques aim to address the root causes of climate change, they can be used to divert political will from real solutions. These interventions are only intended to partially counteract some climate change symptoms. The underlying drivers of climate change (e.g. growing energy consumption, uncontrolled urbanization and industrialization, deforestation, unsustainable agriculture and land use changes) would continue causing climate chaos, which means deploying geoengineering would create a "captive" market.

Although many geoengineering advocates recognize that drastic emissions reductions are needed to confront climate change, and thus rhetorically insist geoengineering should only be a complement to that, their research feeds the illusion to policymakers that high emissions can continue.

A starting point

Although many geoengineering advocates recognize that drastic emissions reductions are needed to confront climate change, and thus rhetorically insist geoengineering should only be a complement to that, their research feeds the illusion to policymakers that high emissions can continue. In that way, political attention on speculative geoengineering options is already deviating resources from the development of the alternatives that could be a real, permanent solution to the climate crisis.

A starting point for a discussion on confronting climate change should be to acknowledge that traditional emission reduction strategies such as energy efficiency, replacing fossil fuels with renewable energies, and retrofitting buildings will not suffice to reach the objectives of the Paris Agreement. Industrial production and consumption patterns have far exceeded safe planetary boundaries.

What we need is an honest conversation about radical emission reduction pathways that transcend mainstream economic thinking. We also need sound, socially just and culturally appropriate strategies to repay our land-carbon debt by vastly, yet carefully, restoring natural ecosystems.

Developing geoengineering technologies, or rejecting such a trajectory, is a matter of political and social deliberation and choice. It is saying that we would sooner alter our planet than alter our economic system. It is no technical or scientific necessity – it is a defence of a failed status quo.

Geoengineering discussions at the UN

The United Nations has been home to a decade-long discussion on geoengineering based on the precautionary approach and environmental and social concerns, with its center of gravity at the UN Convention on Biological Diversity (CBD). At the CBD, a de facto moratorium on ocean fertilization was established in 2008,[292] and on geoengineering in general in 2010.[293] More thematically focused, the London Convention/London Protocol to prevent marine pollution adopted a decision in 2013 to prohibit marine geoengineering (except for legitimate scientific research).[294]

The CBD has published two reports on geoengineering that were extensively reviewed by its member governments, including an analysis of the regulatory and legal framework related to the Convention and the possible role of other UN bodies.[295]

Climate manipulation has been a subject of military interests for many decades as a means to control the weather for hostile purposes. The impacts of the hostile use of weather modification by the US against Vietnam led to the adoption of the UN Environmental Modification Treaty (ENMOD) in 1977 to prevent the manipulation of the environment as a means of warfare.[296] Some geoengineering proponents have intentionally denied the reality of these discussions that have already taken place inside the UN system. They argued instead that geoengineering research and experiments can be self-regulated and voluntarily managed through ethical guidelines, codes of conduct and similar measures.[297]

Some pragmatically believe that such 'soft governance' approaches are more in line with the way international governance moves forward in the current geopolitical climate, while others are hoping that some kind of self-regulation or soft regulation of the first links of the geoengineering chain would prevent broader international measures, such as a ban. The political writer Naomi Klein has observed that the tragedy of recent international climate change governance is that the climate change problem emerged to prominence at the height of the so-called Washington Consensus when neoliberal governments did not consider it realistic to make strong decisions, and instead opted for ineffective voluntary and market responses to a problem that required strong multilateral action.[298] It would be a grave mistake to repeat that ideologically-driven error when approaching geoengineering governance.

Self-regulation or partial regulation (thematic, national, regional) of geoengineering experiments and deployment is clearly inappropriate, particularly in the light of the transboundary nature, significant dangers and inherent inequity of impacts that geoengineering proposals imply.

Transboundary nature

Because geoengineering by definition aims to intentionally alter Earth systems such as the atmosphere, the carbon cycle, and implicitly the hydrological cycle, it is transboundary in nature. And because we know very little about the functioning of the planetary ecosystem as a whole and its subsystems, including climate, there is a significant likelihood that instead of improving the climate, geoengineering could make things worse in unexpected ways.[299] Some researchers argue that the governance of CDR proposals should be separate from the governance of SRM because they are technically and spatially different and pose different risks at the place of deployment. But several of the proposed technologies, whether they are considered under the umbrella of CDR/GGR or SRM, share important characteristics that must be considered for their governance.

For instance, ocean fertilization, stratospheric aerosol injection and marine cloud brightening all aim to add huge amounts of additional compounds into dynamic and fragile ecosystems.

Outdoor experiments, including small scale, could create "technological lock-ins," and "entrenchments," "whereby social and technological choices are constrained by pre-existing technological commitments, norms or standards"

It is true that some other CDR proposals, if applied, would take place at the national level, and thus could be governed by national laws. But the aim of climate geoengineering, by definition, is to be deployed at a scale that will affect the global climate, whether SRM or CDR. So, it would be extremely dangerous to leave the decision of deployment only to the national level without considering the impacts of additionality and accumulated effects. The transboundary nature of geoengineering and the unequal distribution of impacts strongly requires that any decision about experimentation and deployment be taken at a multilateral level, with the full participation of those that could be negatively affected and considering many different kinds of impacts simultaneously.

Research and governance – the chicken and the egg?

Geoengineering researchers and promoters have often advocated that their research and experiments would be best governed by voluntary guidelines and codes of conduct. Some are more cautious about deployment, while others think that even deployment could be subject just to national norms.

None of those ideas are commensurate with the dangers of geoengineering, its game-changing role in international politics and its inherent transboundary nature. The majority of research on geoengineering is not aimed to be merely theoretical, but instead is designed to develop a technique, or at least create the conditions to develop geoengineering proposals.

Outdoor experiments, including small scale, could create "technological lock-ins," and "entrenchments," "whereby social and technological choices are constrained by pre-existing technological commitments, norms or standards,"[300] as happened with other technological developments. This leads to a slippery slope of larger field experiments and ultimately deployment.

The trial of the techniques will lead to their "proof of principle," useful to fundraise for more experiments, and will end up with geoengineering being available to powerful actors who could use it unilaterally to advance their interests.

If that governance were to emerge, the countries of the world would be negotiating over not just the amount of carbon and greenhouse gases in the atmosphere and the reliability of measures to reduce that but also a second variable – the amount of heat in the atmosphere and techniques to lessen that heat.

We have seen the international community repeatedly fail to collaborate to address climate change when there was only one variable to argue over (levels of emissions), so why would we believe that they will now be able to establish the strong and durable consensus required to govern the complexities of geoengineering (which in the case of SRM geoengineering, requires technologically varying incoming sunlight and atmospheric heat in a verifiable manner in addition to managing greenhouse gas levels)? [302]

The Paris Agreement, with all its shortcomings, seemed to be a global consensus in the direction that climate change global action should go. But it took only a few months after it came into force for President Trump, as leader of the biggest historical contributor to climate change, to announce this country would withdraw from the agreement.

What would happen if this was the agreement supposed to govern geoengineering and activities were already underway?

Even the threat of geoengineering capabilities will have geopolitical ramifications. As Oxford University Physics Professor Raymond Pierrehumbert expresses, "…it's bad enough that Trump has his hands on the nuclear weapons launch codes. Do we really want to give someone like him the tools to monkey with the world's climate as well?" [301]

Furthermore, geoengineering research is a deviation of resources from the much-needed research on better and just ways to confront climate change. If geoengineering research is carried out at all, it should be limited to open discussions and indoor studies, like comparing computer models to learn more about climatic conditions and the potential impacts of geoengineering. This research would have to be transparent, particularly around funding and commercial conflict of interests. And any closed research must be performed with careful attention to avoid technological lock-in dynamics and not be used politically to shift climate politics.

Is a global consensus possible?

The events of the US election of Donald Trump and his immediate promise to leave the Paris Agreement (which he made true within his first six months in office) is not just a cautionary anecdote about changing conditions. It is pivotal to understanding the conditions for geoengineering governance.

The kind of governance required for geoengineering demands a global consensus to agree on its development and use, in a democratic framework that requires full democratic participation and commitment of all countries and must last for decades and maybe centuries.

Broad societal deliberations must come first

The prospect of controlling global temperatures raises serious questions of power and justice: Who gets to control the Earth's thermostat and adjust the climate for their own interests? Who will make the decision to deploy if such drastic measures are considered technically feasible, and whose interests will be left out?

Because of its inherent conditions and factors, a broad societal deliberation on geoengineering and its governance, including the possibility of going further than a moratorium to establish a ban, is relevant for all of society, and principally for those people and regions that would be adversely affected by geoengineering.

A legitimate discussion on geoengineering governance must be:

- Based on the precautionary principle, taking into account and respecting the existing UN decisions related to geoengineering, such as the decisions that call for de facto moratoria and ban of marine geoengineering.
- Not confined to climate-related issues, because the consequences are more far-reaching than the climate, including weaponization, international equity, intergenerational justice, impacts on other ecosystems (such as biodiversity and oceans), impact on local and national economies dependent on those ecosystems, and indigenous and peasant rights, among others.
- Informed by a rigorous discussion on ecologically sustainable and socially just alternatives to confront climate change and its causes: we must build radical emission pathways that transcend mainstream economic thinking, such as the managed premature phase-out of fossil fossils, sustainable agricultural models, and absolute reductions in global resource and energy consumption through circular economy approaches. We must also make space for sound and careful ecological restoration of the world's ecosystems, first and foremost our rainforests, moors, and oceans. Until this is done, there is no reason to believe that geoengineering is needed and not merely a dangerous deviation of resources from safe, fair, and ecologically sustainable approaches.
- Preceded by participatory, transparent deliberations on the potential impacts of geoengineering and the need for precaution carried at national and regional levels with the full participation of civil society, social movements and Indigenous Peoples. These could feed into international discussions.
- Multilateral, transparent and accountable deliberations, where all governments can freely participate in a democratic manner, open to public scrutiny and with the full participation of civil society organizations, Indigenous Peoples and social movements (especially those most directly affected by climate change), and accountable to the UN in its outcomes.
- Free from corporate influence, including through philanthro-capitalists, so that private interests cannot use their power to determine favourable outcomes or to promote schemes that serve their interests.
- Directed by obligatory, public and non-ambiguous conflict of interest policies that prevent researchers with commercial interests in geoengineering from acting as "independent" expertise.
- Respectful of existing international laws, including those protecting peace and security, human rights, indigenous rights, biodiversity and national sovereignty, particularly to ensure that any activity undertaken in a country does not cause damage to the environment of other nations, and those prohibiting hostile acts of environmental modification.
- Mindful of concomitant crises, especially hunger, poverty, inequality, loss of biological diversity, ecosystem destruction, atmospheric pollution and ocean acidification.
- Cognizant that neither the seriousness of the climate crisis nor a lack of scientific knowledge can be used to justify experimentation, especially in the view of possible unintended consequences of geoengineering.
- An agreed global multilateral governance mechanism must strictly precede any kind of outdoor experimentation or deployment.
- A ban on geoengineering deployment is a governance option that must be kept open and upheld.

Participatory, transparent deliberations on the potential impacts of geoengineering and the need for precaution should be carried at national and regional levels with the full participation of civil society, social movements and Indigenous Peoples.

Please see Annex 1 for detailed information on intergovernmental negotiations and decisions related to geoengineering at the United Nations. Annex 2 provides information on some of the non-governmental governance initiatives.

Chapter 7

The Way Forward

There are ecologically sound and socially just pathways out of the climate crisis – these need to be recognized and supported. We cannot allow fear or paralysis to lead us toward extreme and dangerous techno-fixes like geoengineering.

A radical realism

The climate crisis is grave, but we will fail to solve it if we fall into the same techno-induced trance that allowed climate chaos in the first place. It will surely not be solved if we leave it up to the "Climate Emperors" and the Geoclique, who are stockpiling an engineering arsenal to target climate effects rather than treat the underlying pathology. What we urgently need is to challenge the root causes of climate change and infuse an alternative approach with radical realism. The causes of climate change are widely known. The primary cause is a carbon-oil-addicted civilization with its industrial systems of mass production and mass consumption. Just 10% of the global population is responsible for almost 50% of global CO_2 emissions.[303] A phase-out of existing fossil fuel infrastructure for coal, oil and gas exploitation must begin immediately if we are serious about confronting climate change and protecting the future for our children and grandchildren.

One of the most promising radical alternatives is, in fact, not even an "alternative," but a reality hidden in plain sight: the peasant food web – made up of peasants, pastoralists, urban gardeners, fisherwomen and fishermen – which is already able to feed 70% of the world's population with less than 25% of the land, water and resources.[304] Their work prevents emissions and cools the Earth at the same time. The industrial food system uses more than 80% of the land, fuel and resources, and is the largest emitter of greenhouse gases on the planet.

We are not powerless – even those of us who live most, or all, of our lives outside the peasant food web. Diverse alternatives to carbon-addiction that can be affirmed, expanded and/or developed include supporting mass sustainable public transportation, zero-waste policies and policies that target large emitters; avoiding overconsumption and consumerism; reducing air travel; restoring forests and other natural ecosystems, and many others. There are ecologically sound and socially just pathways out of the climate crisis – these need to be recognized and supported. We cannot allow fear or paralysis to lead us toward extreme and dangerous techno-fixes like geoengineering.

The norm is a rejection of geoengineering

Rejection and dismissal are the overwhelming responses of most peoples and governments when they are given basic information about the mechanisms of geoengineering. Geoengineering's risks – too many and too high – render it unacceptable. (Even most geoengineering proponents claim to reject it, but argue in its favor as a lesser evil or as an insurance policy.) Nonetheless, through the usual channels – media, the academy, and powerful governments with the luxury, means and hubris to throw their weight around – geoengineering is undergoing "normalization," becoming a climate-change response option instead of being seen for what it truly is: a lurid set of proposals which, if realized, could devastate ecosystems and communities.

One step in the normalization process is to convince governments and the public that 'science' (and, specifically, the IPCC climate change scenarios) has determined that we have already passed the threshold by which CO_2 emissions reductions alone can save us from climate catastrophe. It follows, then, that we must 'inevitably' resort to Carbon Dioxide Removal techniques, at the very least. This rationale often accompanies a disregard – or ignorance – of the potential of natural CO_2 removal systems, such as natural forests and ecological ecosystem restoration, peasants' and small farmers' agroecological practices, among many others.

Although the climate situation is undoubtedly serious, the assumptions embedded in models used by the IPCC are based on a set of parameters (physical, climatic, economic) that are estimates and that, by choice, diminish certain variables and interactions and enhance others.

The models are therefore not fixed realities. There is much work to be done to thoroughly analyze and critique, for example, the mainstream economic models upon which conclusions about our future emissions reductions are drawn.[305] The deep transformations required from our economies and societies to allow for a climate-just, 1.5°C world represent a major political challenge. However, geoengineering does not constitute a viable alternative. There are political, social, cultural, environmental, economic, ethical, moral, intergenerational, rights-based (the rights of women, workers, Indigenous Peoples, peasants) reasons to oppose it, making geoengineering an undeniably false solution.

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The existing, better "alternatives" need to be championed because their current and potential contributions are consistently denied (as is often the case when peasant, local and agroecological agriculture is the topic of discussion[306]). Other alternatives must be developed as well. Geoengineering distracts policymakers from the urgency of supporting those realities and developing those alternatives.

Maintain and reinforce the moratoria

The decisions at the Convention on Biological Diversity that established a de facto moratorium on geoengineering, as well as the London Convention /London Protocol's decision to ban ocean fertilization and marine geoengineering,[307] are crucial and must be maintained and reinforced. The decisions are important, particularly to Southern governments and civil society, because it is a warranty that debates can take place and decisions can be reached before having to suffer the impacts of unilateral geoengineering actions taken by a powerful government or a coalition of governments.

It will depend on responsible governments and civil society to continue defending and advancing these decisions, and urging other national governments to honor them. Both landmark decisions signaled the need for a strict, precautionary approach to geoengineering. Any policymaking forum or private sector discussion of geoengineering must be guided by the CBD moratorium, a decision taken by consensus of 193 governments.

Discussions that try to advance geoengineering outside this framework are an explicit or implicit undermining of the notion that we need to have informed, multilateral, democratic and transparent governance frameworks for geoengineering technologies – including the possibility of a ban on some or all them.

The CBD moratorium must also be protected against attempts by some governments to preempt the decisions by pulling the issue of geoengineering out of the CBD, which would confine the discussion to a narrow consideration of climate effects. The impacts of geoengineering on biodiversity and over the indigenous, peasant and local communities that maintain biodiversity, and whose livelihoods depend on biodiversity, are and will remain under the jurisdiction of the CBD. Further, socioeconomic impacts as they pertain to biodiversity are within the purview of the CBD.[308] Certainly, other UN bodies, principally the General Assembly, should discuss the broad implications of geoengineering and could consider a ban or other measures to pre-empt action that could bring about greater climate inequities and/or negative environmental and health impacts. Panels such as IPBES or IPCC, limited to scientific considerations, are not equipped to consider the broader impacts of geoengineering.

Stop open-air experiments

For any geoengineering technique to have an impact on the global climate, it will have to be deployed on a massive scale. It is not possible to conduct experiments that could demonstrate the effectiveness or safety of any geoengineering technique without, in effect, deploying the technology. Geoengineering "experiments" are an oxymoron. To have a significant impact on the global climate, they would need to be so large and sustained over such a prolonged period of time that they could no longer be called experiments. Experiment and deployment would be indistinguishable, and the impacts and side effects could not be recalled.[309]

"Small scale," open-air experiments will not provide useful knowledge about the effects of deployment on climate, but may be useful to test hardware and to establish a "proof of principle" that could encourage governments to invest in a particular technology without a necessary and full prior societal debate, and in the absence of an essential, democratic, internationally agreed framework for governance. Furthermore, any experiment that is not done "for scientific purposes" and "in a controlled setting," among other conditions, violates the CBD moratorium. All open-air SRM experiments, for example, are by definition not carried out in controlled settings and pose a risk of affecting other territories. Outdoor experiments cross a political red line, and should not be allowed to move ahead.

Work for a ban

There are many arguments for banning unproven, untestable geoengineering technologies,[310] but the risk of weaponization – with the potential to bring greater disruption to the global climate – is of great concern, and the possibility cannot be ignored by the United Nations. Geoengineering's inherently dual-use nature – like weather modification before it – should be enough for the UN to consider adopting a ban on all or some geoengineering technologies.

Broad societal debates, broad frameworks

The consequences and potential impacts of geoengineering need to be discussed around the world, in diverse dialogue formats and with a wide diversity of voices. Especially crucial to include are those that will be most affected by geoengineering – and by climate change – and those far removed from the centers of technological power (dominated by Northern, Western, white, technophile men) which offered geoengineering as a credible "solution" in the first place.

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Social and ecological needs, governance, ethics, climate justice, geopolitics, human rights, gender rights, intergenerational equity, among others, should all be on the agenda. The societal deliberations must start from the grassroots of society; if not, it's unlikely the grave risks and the daunting policy and governance challenges will remain front and center, and the discussions will likely end up a rhetorical exercise.

Hands Off Mother Earth!

Geoengineering – as a set of techniques and as a political idea – is not fundamentally about developing a new climate change response option; geoengineers aren't out to simply lower the temperature or reduce greenhouse gases; they aren't after an "anthropocene" correction, in which humans attempts to rectify their own negative impact on Earth and its ecosystems. Geoengineering makes possible the restructuring of Earth itself – geoengineering is not an attempt to erase the anthropos (man) of the anthropocene, but to put anthropos front and center. Geo (derived from the Greek Gaia, goddess of the Earth), in scientific terms, refers to the self- regulating, regenerative emergent power that comes from the totality of Earth systems working together. Gaia also has an older root. For indigenous cultures, Mother Earth, Pachamama, is the sacred, spiritual maternal spirit of Earth.

By attempting to geoengineer the Earth, we necessarily technologize and instrumentalize Gaia. The underlying concept is to transform Gaia herself and how we view and relate to her. Her climates, forests, oceans and soils are rendered first as data – climate data, carbon data, solar reflection data – to be redirected, rewired and micro-managed. Models tell us that if we inject her here, she will weaken there. If we whiten here, she will burn up there. Ultimately, perfecting geoengineering – "hacking the Earth" – means turning the planet into a conceptual cyborg for human beings to programme and manipulate and regulate.

Notions of nature as separate from human agency – notions of the wild, the sacred, of unpredictability and transcendence – are tidied away in the building of models, interventions and the machine/computer metaphor. Just as we have become accustomed to living in synthetic environments such as cities, so our entire home planet becomes recast as a synthetic habitat. Even the colour of the sky is determined by the geoengineers' palette.

For those already living in cities and human-made environments, re-making Earth's systems "in our own image" may seem a smaller step, but for those who still exist closer to natural ecosystems, it significantly changes the realities of existence and relation to nature. For all of us, but particularly for the peasants, artisanal fisherwomen and men, pastoralists, Indigenous Peoples and all communities that directly depend on biodiversity for their livelihoods, handing the levers of control over natural processes to geoengineering represents not just a psychic loss but also a colossal risk. If it goes wrong, and it will, it could threaten subsistence for entire countries and regions, particularly in Asia, Africa and Latin America. To move forward, the geoengineering project must deny the complex, dynamic and interconnected ecosystems, and the diversity of cultures that make up Mother Earth.

[R]esponding to geoengineering is not just a task for scientists, technologists, risk assessors, "environmentalists" and climate policy wonks. It necessarily involves all who inhabit this planet in diverse, vibrant and interdependent ways.

A full societal response to geoengineering's big bad fix, therefore, must not only address the technical deficiencies of the fixes proposed, but it must also say clearly and unambiguously why viewing the Earth as a machine to be fixed is a fundamentally wrongheaded view of our home to begin with. This is why responding to geoengineering is not just a task for scientists, technologists, risk assessors, "environmentalists" and climate policy wonks. It necessarily involves all who inhabit this planet in diverse, vibrant and interdependent ways.

The network of organizations and communities involved in deliberations and activism against geoengineering must therefore include women's organizations, trade unions, farmers, fishers, faith groups, ecologists, youth organizations, peasant organizations, Indigenous Peoples and more. As expressed by the founding organizations of the 'HOME' campaign at Cochabamba, Bolivia in 2011, to tighten our technological grip on planetary systems will only make things worse. Instead, this is a moment to relinquish intervention and let diverse ecosystems find their own path to recovery – to "re-wild" our home along with a diversity of cultures and ways of developing in harmony with nature. To geoengineers and all those who disrupt those life-sustaining relationships between communities and Mother Earth, we will continue to insist: our planet is not your laboratory – "Hands Off Mother Earth!"

Annex 1

Geoengineering at the United Nations

Geoengineering in the Convention on Biological Diversity

The United Nations Convention on Biological Diversity (CBD) has been discussing geoengineering since 2007. The CBD currently has 196 Parties, making it a "universal treaty." However, the US is not a Party to the CBD.

Geoengineering, including ocean fertilization, has been negotiated at five Conferences of the Parties (COP), resulting in consensus decisions related to geoengineering taken by more than 190 governments at COP 9 (Germany, 2008), COP 10 (Japan, 2010), COP 11 (India, 2012), COP 12 (Korea, 2014) and COP 13 (Mexico, 2016).

Previous to these decisions, the CBD had elaborated and submitted for review ten information documents, presented and discussed prior to the COPs at the meetings of the CBD SBSTTA (Subsidiary Body on Scientific, Technical and Technological Advice) at SBSTTA 13, 14, 16, 18 and 19, spanning from 2007 to 2016.

The CBD has produced three peer-reviewed reports in their Technical Series Reports: TS 45 on Scientific Synthesis of Ocean Fertilization on Marine Biodiversity (2009)[311]; TS 66 on Technical and Regulatory Matters of Geoengineering in Relation to the CBD (2012)[312]; and TS 84, an Update on Climate Engineering in Relation to the CBD: Potential Impacts and Regulatory Framework (2016).[313]

In 2008, after several rounds of discussions and taking into account a call for "utmost caution" from the London Convention,[314] the CBD took the consensus decision IX/16 C calling for a moratorium on ocean fertilization, urging governments to ensure that no fertilization activities would take place until a series of stringent requirements are met, including that a "global, transparent and effective control and regulatory mechanism is in place."

Excerpt from decision CBD IX/16:

> *4. Bearing in mind the ongoing scientific and legal analysis occurring under the auspices of the London Convention (1972) and the 1996 London Protocol, requests Parties and urges other Governments, in accordance with the precautionary approach, to ensure that ocean fertilization activities do not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks, and a global, transparent and effective control and regulatory mechanism is in place for these activities; with the exception of small scale scientific research studies within coastal waters. Such studies should only be authorized if justified by the need to gather specific scientific data, and should also be subject to a thorough prior assessment of the potential impacts of the research studies on the marine environment, and be strictly controlled, and not be used for generating and selling carbon offsets or any other commercial purposes.*[315]

Following this, in 2010, the CBD took a landmark consensus decision on a de facto moratorium on geoengineering in general, to ensure that, in line with its previous decision on ocean fertilization, "no climate-related geoengineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts."

Excerpt from decision CBD X/33:

> *(w) Ensure, in line and consistent with decision IX/16 C, on ocean fertilization and biodiversity and climate change, in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity*

take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment;

(x)Make sure that ocean fertilization activities are addressed in accordance with decision IX/16 C, acknowledging the work of the London Convention/London Protocol; [316]

In this decision, in the definition of geoengineering, "carbon capture and storage (CCS) from fossil fuels" (but not from bioenergy) was not considered geoengineering by the CBD.[317]

Both moratoria leave a space for "small scale" experiments, but only "if justified to gather scientific data" and with a list of prior requirements to be fulfilled before they proceed, including a thorough prior environmental impact assessment; that they are carried out in a "controlled setting" (thus not in open air or fields); and ensuring that no transboundary impacts would occur. In the case of ocean fertilization, it is also stated that any experiments carried out can "not be used for generating and selling carbon offsets or any other commercial purposes."

For the details of the decade-long negotiations and decisions at CBD, the Convention opened a special chapter on its website.[318]

Governments at the CBD consider these decisions to be highly relevant, to the point that three geoengineering experiments have been interrupted after being denounced as violations of the CBD decisions. These are: the ocean fertilization experiment LOHAFEX by India and Germany;[319] the private Haida Salmon Restoration Corporation (HSRC) ocean fertilization experiment near Haida Gwaii, Canada;[320] and one experiment devised to test Solar Radiation Management equipment, the Stratospheric Particle Injection for Climate Engineering project (SPICE) in the UK.[321]

In this spirit, the discussion on geoengineering at COP13 in 2016[322] was brief because it had been discussed in the previous SBSTTA 19, and the recommendation from SBSTTA came without any brackets (areas of disagreement) because any differences had been settled in SBSTTA. Although the decision notes that only a few countries had informed about their activities related to geoengineering, as requested by decision XI/20, this does not mean that countries do not care about the issue. On the contrary, the fact is that most countries are not pursuing nor have the intention to pursue any form of geoengineering, not even research, and thus had nothing to inform.

In the 2016 CBD decision, the CBD reaffirmed the application of the precautionary approach and the obligations of States to avoid transboundary harm, as well as affirming that requirements on environmental impact assessment "may be relevant for geoengineering activities, but would still form an incomplete basis for global regulation," an argument for the need to maintain the moratoria. In its studies on a legal and regulatory framework, the CBD lists different UN bodies whose area of work and mandate would be affected or violated by geoengineering and should thus have a role related to its governance, including obviously the CBD.

Civil Society and Geoengineers on the CBD moratorium

Within the CBD, the CBD Alliance, which is made up of more than 400 civil society organizations, as well as the Global Youth Biodiversity Network (GBYN) and the International Indigenous Forum on Biodiversity (IIFB) have worked for and actively support both moratoria.

Although the CBD is by far the most representative and active UN body to discuss geoengineering and it established key pieces of governance related to its mandate and constituency, geoengineering promoters have a consistently passive-aggressive campaign trying to denigrate its decisions. Their behaviour shows how influenced they are by the US debate, a country that is not a Party to the CBD. However, because the CBD is considered a universal treaty, diplomacy requests all countries respect its decisions.

The explicit arguments by geoengineers and their allies is that the CBD decisions are not binding, and that the moratorium on geoengineering has exhorting language.

The latter argument is also used by a handful of governments – all of them home to geoengineering programs, including some commercial enterprises – to question whether the decision is a moratorium.

But all decisions taken in a United Nations Conference of the Parties are binding to its members, because to be a Party, each country needs to sign, ratify and commit to follow the Convention's decisions. Although the word "moratoria" is not in the text, all the parties are explicitly invited to make sure that no geoengineering activities take place unless a considerable list of considerations are met, including "appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts."

Furthermore, the strength of a decision in United Nations is not only about its text, but also about the importance that governments and civil society give to the decision and how it is used and defended. In the case of the geoengineering, the decisions are considered highly relevant decisions, equivalent to moratoria, by a large majority of its members. The interruption of the three cited geoengineering experiments[323] was based on the affirmation of the moratoria, demonstrating the diplomatic weight of the decisions.

ENMOD Convention: war on climate change or just war?

Many geoengineering techniques have latent military purposes and their deployment could violate the UN Environmental Modification Treaty (ENMOD), which prohibits the hostile use of environmental modification.

The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) has been in force since 1978 and has been ratified by 77 states.[324] It prohibits the use of environmental modification and commits parties "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party" (Article I).

Article II defines environmental modification techniques: "any technique for changing – through the deliberate manipulation of natural processes – the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space."

This definition encompasses many geoengineering technologies currently under active research and development.

ENMOD doesn't prohibit environmental modification for peaceful purposes, so it would only apply directly to geoengineering if it were explicitly developed or deployed as warfare. But once the tools are developed, let's say with the aim to alleviate symptoms of climate change, who will make sure that they are not used for hostile purposes? What happens if a "peaceful use" causes unintended harm?

In light of the inherent dual purpose capability of geoengineering, and in keeping with Article V of ENMOD, which allows a Party to request a review of another Party's activity if the former "has been harmed or is likely to be harmed as a result of violation of the Convention," the Convention could review some Parties' initiatives to plan, support or conduct experiments in environmental modification (geoengineering) that could have wide-spread, long-lasting or severe effects, causing potential damage or injury to other parties.[325]

The London Convention, CCS and marine geoengineering

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, also known as the London Convention (LC) (1972), and its London Protocol (LP) (1996) are global agreements that regulate dumping in the seas. The LC and LP have therefore taken regulatory decisions on marine geoengineering, especially ocean fertilization and carbon capture and storage, when it is intended to be stored in sub-seabed geological formations.

In 2006, the LP was amended to cover the transboundary aspects of carbon capture and storage (CCS), e.g., CO_2 streams for disposal in sub-seabed geological formations. Guidelines and an assessment form were designed to this end. A permit may be issued to allow for storage of CO_2 in sub-seabed geological formations in national territory.

However, the trans-boundary export of CO_2 for CCS is prohibited, according to article 6 of the London Protocol, which doesn't permit the export of wastes and other matters for dumping in the marine environment. An amendment to this article has been approved, but it has not entered into force and the progress of ratifications is slow.[326]

On ocean fertilization, in 2007, the governing bodies of the London Convention and the London Protocol endorsed a "Statement of Concern regarding iron fertilization of the oceans to sequester CO_2" of their Scientific Groups, and urged States "to use the utmost caution when considering proposals for large-scale ocean fertilization operations." In the same decision, LP took the view that "given the present state of knowledge regarding ocean fertilization, large-scale operations were currently not justified."

In 2008, the Governing Body reaffirmed the previous resolution, and went further to agree that,

> *"given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed. To this end, such other activities should be considered as contrary to the aims of the Convention and Protocol and not currently qualify for any exemption from the definition of dumping in Article III.1(b) of the Convention and Article 1.4.2 of the Protocol."* [327]

In 2010, a thorough "Assessment Framework for Scientific Research Involving Ocean Fertilization" was developed and adopted, to make sure that any proposals on ocean fertilization are only for scientific purposes and not contrary to the aims of the LC/LP.[328]

In 2013, after further reasoning, the London Protocol went further to adopt a broader decision to prohibit marine geoengineering.[329] The decision applies to the technologies that are included in an annex, which to date lists only ocean fertilization because other techniques have not yet been thoroughly considered by the LP.[330]

The resolutions of the LC/LP regarding marine geoengineering and CCS are highly relevant, particularly in the framework of the ocean fertilization and other geoengineering decisions at the CBD, which has more Parties.[331]

UNGA on ocean fertilization

Ocean fertilization was also the subject of negotiations at the United Nations Conference on Sustainable Development (Rio+20) in June 2012.The outcome document The Future We Want states in paragraph 167 that:

> *"167. We stress our concern about the potential environmental impacts of ocean fertilization. In this regard, we recall the decisions related to ocean fertilization adopted by the relevant intergovernmental bodies, and resolve to continue addressing with utmost caution ocean fertilization, consistent with the precautionary approach."*

It should be noted that to "recall" the decisions in this context means to reiterate or draw attention to them, and so confirms that the decisions of the CBD and the LC/LP are still of good standing, as well as that States are still concerned about the potential environmental impacts of ocean fertilization.

The declaration was later confirmed in the United Nations General Assembly[332] resolution A/RES/66/288.

UNFCCC, Paris Agreement and geoengineering

The UN Framework Convention on Climate Change (UNFCCC) has not considered geoengineering as such in its official agenda.

The UNFCCC has debated the issue of Carbon Capture and Storage (CCS) since 2005, and it has been quite a controversial issue. Despite the controversy, at COP 16 in 2010, CCS was approved to be included in the Clean Development Mechanism.[333]

In 2014, a Technical Expert Meeting on CCS was held. Unfortunately, rather than an open discussion on all aspects of CCS, including risks, impacts, viability and efficiency, the event was basically a CCS showcase by corporations, including the oil industry, to sell the technology to governments and ask for various levels of public support, including from the UNFCCC.[334]

In 2015, the UNFCCC approved the Paris Agreement,[335] which sets a goal to limit the increase of the average global temperature (Article 2) and means to achieve that goal (Article 4).

Paris Agreement, Article 2:

This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) ***Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels****, recognizing that this would significantly reduce the risks and impacts of climate change; (...)*

Paris Agreement, Article 4:

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, ***and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century,*** *on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.*

(Emphasis added)

The adoption of the Paris Agreement also included the decision to convene a facilitative dialogue in 2018 to take stock of the progress towards the goals referred to in Article 4 and the preparation of Nationally-Determined Contributions (NDC).[336]

Prior to the agreement, governments had made voluntary GHG reductions commitments at COP 16, Cancun. After the Paris Agreement, each Party had to deliver a plan to the UNFCCC for its intended NDC to confront climate change. When those were aggregated, the sum would result in an increase of the global average temperature of 2.9-3.4 degrees Celsius, according to UNEP.[337]

Several points in the Paris Agreement – and the gap that appears between the NDC commitments and the Paris Agreement goals – have been interpreted by geoengineering researchers and promoters as an opportunity to advance geoengineering proposals. The key points that they refer to are keeping the temperature "well below 2 degrees" (which according to the IPCC would require drastic emissions cuts up to 70 % before 2050, but some cumulative effects of certain GHGs will continue),[338] combined with the possibility to postpone or avoid making those reductions, by "achieving a balance" between emissions and sinks. Some researchers emphasize the role of SRM to lower the temperature, while others emphasize CDR proposals to suck carbon out of the atmosphere or a mix of several technologies. Others cynically call for a "cocktail" of geoengineering (as if climate crisis were a dinner party), mixing SRM and CDR technologies to attain these goals.[339]

Other treaties that could be violated by geoengineering experiments and deployment

Beyond the treaties mentioned above, there are other treaties with provisions related to geoengineering that could be violated by experiments and deployment of geoengineering. These include the Vienna Convention on Protection of the Ozone Layer and Montreal Protocol; the Convention on Long Range Transboundary Air Pollution (Europe, LRTAP); the International Covenant on Economic, Social and Cultural Rights (ICESCR); the UN Convention on the Law of the Sea (UNCLOS); the Outer Space Treaty; the United Nations Convention to Combat Desertification (UNCCD); the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus Convention, Europe); the Antarctic Treaty System.

The list also includes multilateral institutions with mandates related to geoengineering activities and impacts, specifically the United Nations General Assembly, the United Nations Environmental Assembly, the International Security Council, the International Criminal Court, the International Court of Justice, the United Nations Human Rights Council, the World Meteorological Organization, among others.[340]

Annex 2

Non-governmental Initiatives on Geoengineering Governance

All existing non-governmental initiatives to discuss geoengineering governance are based in the Global North, principally in North America, UK and Germany. The majority are based in academia and their main focus has been the governance of research and experiments. Most of them refer to voluntary guidelines, codes of conduct and similar self-governance initiatives for research and experiments, although most recognize that governments would ultimately need to decide whether or not to deploy. (Like the Geoclique itself, almost all of the key movers in these governance initiatives are European or American white men – unsurprising because geoengineering, as a techno-fix for the climate crisis caused by countries and corporations in the North, is itself the brainchild of scientists from the North).

In 2010, an international conference on "climate intervention" was held in Asilomar on the Pacific coast of California, convened by two US organizations. The goal was to develop guidelines for "the scientific community" to govern themselves on geoengineering research and experiments. The choice of location was inspired by the 1975 Asilomar meeting on recombinant DNA, which established voluntary guidelines on genetic engineering and was instrumental in persuading the US Congress that it was unnecessary to legislate control over the technology, thus delaying independent oversight and regulation on GMOs for decades. The 2010 conference gathered 175 scientists and geoengineering entrepreneurs – just four of whom hailed from developing countries.

SRMGI: Preaching to The South

On the heels of its 2009 report on geoengineering, the UK Royal Society initiated a Solar Radiation Management Governance Initiative (SMRGI) that, among other things, became a forum for negotiating the Society's recommended "de minimis standard for regulation of research."[341] SRMGI was established to reach out to scientists, governments and civil society, particularly in developing countries, to discuss SRM proposals. The project was launched by the UK Royal Society, the Third World Academy of Sciences (TWAS) based in Trieste, Italy, and the Environmental Defense Fund in Washington DC. It is based in and driven from the North but primarily attempts to organize meetings in the Global South.

SRMGI describes itself as "an international, NGO-driven project that seeks to expand the global conversation around the governance of SRM geoengineering research,"[342] particularly in developing countries and emerging economies.[343] It claims it does "not take a stance on SRM research or the use of SRM" but serves to promote dialogues. However, the heavy presence of the Geoclique in its initial working group[344] has made a mark on the project. SRMGI Project Director Andy Parker characterizes himself as a reluctant skeptic unable to dismiss the compelling arguments in favor of considering SRM research.[345]

Since 2010, SRMGI has convened academics, scientists, some government officials and a few civil society representatives in key developing countries to discuss SRM and issues related to it, but has included few critics, based on the reports of the meetings.[346]

The C2G2: pushing geoengineering governance into the mainstream

In 2017, a new initiative on geoengineering governance was established: the Carnegie Climate Geoengineering Governance Initiative (C2G2). It aims to incorporate the views and perspectives of a broader range of organizations to advance the discussion on and creation of geoengineering governance. Its work is premised on the interpretation that the discussion on geoengineering governance has been limited to the scientific and research community, and there is a need to bring it to the "global policy-making arena…encouraging a broader, society-wide discussion about the risks, potential benefits, ethical and governance challenges raised by climate geoengineering."[347] Like SRMGI, C2G2 publicly claims to have a neutral stance on geoengineering, neither for nor against testing or potential use, stating that such a decision "is for society to make."[348]

Janos Pasztor heads C2G2; he's a veteran of the UN system and led the climate change support team of former UN Secretary General Ban-Ki Moon. Most members of the C2G2 team also come from Pasztor's former climate change team at the UN. His network and sphere of influence at the UN have proven to be useful in advancing the work of C2G2.

In its inaugural year, the initiative has brought the discussion of geoengineering governance to the top level of some UN agencies and international institutions including churches and religious organizations, and has organized side events and seminars in various intergovernmental processes. It has raised the issue to diplomats and high-ranking government officials in key countries. C2G2 has also participated in some national meetings organized by SRMGI in some developing countries, bringing up governance issues beyond SRM.

In an effort to demonstrate its "neutrality," C2G2 created an Advisory Group comprised of members from diverse backgrounds in academia, government, the UN, research and civil society from industrialized and developing countries who represent interests that promote and oppose geoengineering – and various shades in between. While members are expected to provide advice on substantive issues related to C2G2's work, it is not a decision-making body. The Advisory Group, because of its diverse nature and divergent perspectives on geoengineering, is not expected to reach consensus on positions. Consequently, the positions of C2G2 do not reflect the views of the Advisory Group.[349]

As a high-profile initiative, C2G2's claim of neutrality has been closely scrutinized.[350] The initiative is perceived by prominent members of the Geoclique as an opportunity to advance their work,[351] and indeed, geoengineering promoters have made sure to actively participate in C2G2 activities, but, so too, have a handful of critics.

Surprisingly, given its steadfast claim of neutrality, C2G2 has recently taken an organizational policy position. In late 2017, C2G2 articulated its priorities, which included "putting solar geoengineering on hold until (i) the risks and potential benefits are better known, and (ii) the governance frameworks necessary for deployment are agreed."[352] C2G2 explains its "aim to strike a balance between those interested in researching solar geoengineering to see if there is sufficient merit, weighed against risks, in potentially deploying it, and those who want to ensure that deployment of solar geoengineering does not occur for fear of making matters worse."[353]

This mirrors the perspective that Geoclique insider and SRM promoter David Keith and environmental lawyer Edward Parson articulated in 2013; they, too, aim to strike a balance between scientists "who want to do it" and "legitimate societal interests..."[354] – which will accord them the freedom to proceed with research. Keith and Parson explain that if the cost of getting "to do it" is "a modest regulatory burden, enforced by governments,"[355] they are willing to pay it. It's no surprise that geoengineers think in those terms, but it's more surprising for C2G2 – which claims not to be "for or against" geoengineering – to be concerned with striking "a balance." The debate about geoengineering's merits and deficits and its governance is for the United Nations to undertake after broad, bottom-up societal debates, not after trying to "strike a balance" between geoengineers and the rest of society.

Academic Working Group on International Governance of Climate Engineering

The Forum for Climate Engineering Assessment (FCEA) is an initiative of the School of International Service at American University in Washington, DC, and it is mostly composed of academics. It was constituted in 2013, "out of a recognition that the conversation about climate engineering or 'climate geoengineering' responses to climate change was growing rapidly in importance, yet was narrowly restricted in terms of the scope of actors and interests." The FCEA later created an Academic Working Group (AWG) on International Governance of Climate Engineering, an international group of senior academics assembled to give their perspectives on the international governance of climate engineering research and potential deployment, particularly focusing on proposed solar radiation management technologies.[356]

The FCEA staff has tried to gather different opinions on SRM in their work, publishing a mix of geoengineering critique and geoengineering promotion.[357] Its Board of Advisors includes a handful of Geoclique regulars.[358]

The Academic Working Group (AWG) on International Governance of Climate Engineering does not pretend to be "neutral" on geoengineering, but is rather looking for ways to govern SRM, to facilitate its research and deployment under certain conditions.[359]

Endnotes

Chapter 1 – Geoengineering: The Emperors' New Climate

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Chapter 2 – Geoengineering: the Technologies

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Glossary of Geoengineering Technology Acronyms

BECCS: Bioenergy with Carbon Capture and Storage
CCS: Carbon Capture and Storage
CCUS: Carbon Capture, Use and Storage
CDR: Carbon Dioxide Removal
DAC: Direct Air Capture
EOR: Enhanced Oil Recovery
GGR: Greenhouse Gas Removal
MCB: Marine Cloud Brightening
OF: Ocean Fertilization
SAI: Stratospheric Aerosol Injection

ETC Group

ETC Group works to address the socioeconomic and ecological issues surrounding new technologies that could have an impact on the world's poorest and most vulnerable people. We investigate ecological erosion (including the erosion of cultures and human rights); the development of new technologies (especially agricultural but also other technologies that work with genomics and matter); and we monitor global governance issues including corporate concentration and trade in technologies. We operate at the global political level. We work closely with partner civil ociety organizations (CSOs) and social movements, especially in Africa, Asia and Latin America. **www.etcgroup.org**

etc GROUP monitoring power tracking technology strengthening diversity

Biofuelwatch

Biofuelwatch provides information, advocacy and campaigning in relation to the climate, environmental, human rights and public health impacts of large-scale industrial bioenergy and the bioeconomy. We promote policy decisions on land use and environmental permitting which prioritise the protection of climate, environment, social justice, public health and active citizenship. In the UK, our current key focus is biofuels and biomass electricity. Our international work currently focuses on risks of biotechnology developments for the "bioeconomy" (genetic manipulation of crops, trees and microbes), and land based approaches to climate geoengineering ("biosequestration"). **www.biofuelwatch.org**

biofuelwatch

Heinrich Böll Foundation

Fostering democracy and upholding human rights, taking action to prevent the destruction of the global ecosystem, advancing equality between women and men, securing peace through conflict prevention in crisis zones, and defending the freedom of individuals against excessive state and economic power – these are the objectives that drive the ideas and actions of the Heinrich Böll Foundation. We maintain close ties to the German Green Party (Alliance 90 / The Greens) and as a think tank for green visions and projects, we are part of an international network encompassing well over 100 partner projects in approximately 60 countries. The Heinrich Böll Foundation works independently and nurtures a spirit of intellectual openness. **www.boell.de/en**

HEINRICH BÖLL STIFTUNG

The Big Bad Fix

The Case Against Climate Geoengineering

Following ETC Group's 2010 "Geopiracy" report, this report exposes the context, goals, actors and rapid developments underway to advance climate manipulation, or geoengineering. The new framing from geoengineers is that we must accept these dangerous technofixes because they cannot see any other alternative to stall or prevent climate havoc.

Since "Geopiracy," the narrative has evolved to play on growing public alarm about the climate crisis and the technologies have advanced, but the actors and their goals remain the same. From adjusting the Earth's thermostat to changing the chemistry of the oceans, geoengineering proposals pose unacceptable threats to people and the environment.

"Geoengineering is a dangerous and risky distraction from real solutions to the climate crisis. We need a complete transformation of our energy systems, food systems and economic systems. But powerful vested economic interests are desperate to divert our attention from system change and from radical emissions reductions needed at the source. Friends of the Earth International rejects large-scale geoengineering as an unproven technology which could lead to land or resource grabbing and dispossession of local communities. This report is important reading for all of us concerned about the impacts of geoengineering and what can be done about it."

Karin Nansen,
REDES-AT Uruguay,
Chair of Friends of the Earth International

"It is unacceptable that while nations suffer the brutal impacts of climate change, profit-driven corporations plan to colonize the sky through geoengineering and lock in climate inaction. The world must be weaned from fossil fuels, cut emissions at the source and not permit any manipulation of the climate that has the potential to pile more harm on Africa and other territories. This report is excellent to understand the real aims of geoengineering and should be required reading for all climate justice activists."

Nnimmo Bassey,
HOME Foundation,
Nigeria

"As Indigenous Peoples, we are unified in our opposition to all forms of geoengineering. As human beings, we are entirely dependent upon our respectful relationship with the natural world. We are now faced with the consequences of the exploitation of the natural world that threaten the future existence of all life on Mother Earth. Our Indigenous traditional teachings, lifestyles, spirituality, cultures and leadership of our people has sustained us for millennia and will do so for countless future generations but only if the world adheres to the Natural Laws of Creation and the Precautionary Principle. Geoengineering acts against all of those."

Tom BK Goldtooth,
Indigenous Environmental Network, USA

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