Darken the sky and whiten the earth – The dangers of geoengineering

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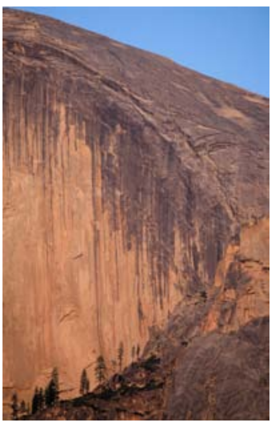

Geoengineering is the intentional, large-scale intervention in the Earth's oceans, soils and atmosphere, most often discussed in the context of combating climate change.

The 'proof of principle' that cumulative, local interventions in ecosystems can bring about planetary-level effects is beyond dispute. That's why we have human-induced climate change. However, as we approach so-called 'climate tipping-points', another notion is quickly gaining ground: that we can use geoengineering as an emergency measure to intervene purposefully and to correct the inadvertent but serious harm we've done.

Geoengineering is the intentional, large-scale intervention in the Earth's oceans, soils and atmosphere, most often discussed in the context of combating climate change. It can refer to a wide range of schemes, including: blasting sulphate particles into the stratosphere to reflect the sun's rays (referred to as 'solar radiation management'); dumping iron particles in the oceans to nurture CO_2-absorbing plankton; firing silver iodide into clouds to produce rain; genetically engineering crops so their leaves might reflect more sunlight.

Harvard physicist and geoengineering advocate, David Keith, describes geoengineering in the context of climate change as 'a countervailing measure, one that uses additional technology to counteract unwanted side effects without eliminating their root cause, "a technical fix"' (Keith, 2010a: 494). In other words, geoengineering uses new technologies to try to rectify the problems created by the use of old technologies.

Amidst growing public unease and increasing concentrations of greenhouse gases in the atmosphere, Organisation for Economic Co-operation and Development (OECD) countries, in particular, are feeling the pressure to 'bite the bullet'. They either adopt socially responsible policies to dramatically cut fossil fuel consumption, or they can hope for a more palatable alternative – a 'silver bullet' in the form of technological solutions that may help preserve the status quo without the harmful side effects. This silver bullet option is most strikingly embodied in the notion of geoengineering, and it's gaining favour. Not surprisingly, it is the states in the global North, which are responsible for most of the historic greenhouse gas emissions and have either denied climate change or prevaricated for decades, that seem to be warming most quickly to the geoengineering option. And they would have de facto control over its deployment.

Only the world's richest countries can really muster the hardware and software necessary to attempt rearranging the climate and resetting the Earth's thermostat. Moreover, once the smog clears, the major private sector players in geoengineering will likely be the same energy, chemical, forestry and agribusiness companies that bear a large responsibility for creating our current climate predicament – in effect, the 'old guard geoengineers' that profited from climate changing industries of the twentieth century.

Opting for geoengineering flies in the face of precaution, and history. Even some of those who would like to see large-scale investment in the field are quick to acknowledge that we do not know enough about the Earth's systems to risk intentional geoengineering; we do not know if geoengineering is going to be inexpensive (as proponents insist) – especially if/when geoengineering doesn't work as intended, forestalls constructive alternatives, or causes adverse effects; we do not know how to recall a planetary-scale technology once it has been released. Techniques that alter the composition of the stratosphere or the chemistry of the oceans are likely to have unintended consequences as well as unequal impacts on both ecosystems and societies around the world (Royal Society, 2009: 52).

The governments most open to putting geoengineering options 'on the table' – the United States and United Kingdom in particular, but also several other Annex 1 countries – are the ones that have failed to pony up even minimal funds for mitigation or adaptation action on climate change. Indeed in some quarters the MAG approach (Mitigation, Adaptation and Geoengineering) is already being proposed for discussions on climate change (Institution of Mechanical Engineers, 2009). In practice, this means governments may divert climate change funding from climate change mitigation and adaptation toward geoengineering.

Given the dismal and contested decades of climate negotiations, there is little reason for the governments or peoples of most of Africa, Asia and Latin America to trust that the governments, industries or scientists of the biggest carbon-emitting states will protect their interests. In the absence of demonstrable goodwill by the states likely to conduct geoengineering, the governments of the global South should be suspicious. In the absence of public debate and without addressing the inequalities between rich countries and poor countries – in terms of both historical responsibility for climate change and the potential impacts of any technologies deployed to address it – geoengineering deployment would be an act of 'geopiracy'.

What is geoengineering?

Geoengineering refers to new and diverse technologies that are already being routinely classified as solar radiation management (SRM), carbon dioxide removal and sequestration, or weather modification.

Solar radiation management (SRM)

Solar radiation management technologies aim to counter the effects of greenhouse gases by increasing the radiation of sunlight back into space. SRM encompasses a variety of techniques, including: using reflective 'pollution' to modify the atmosphere, blocking incoming sunlight with 'space shades' and covering deserts with reflective plastic. None of these technologies lowers levels of greenhouse gases in the atmosphere; the intention is only to counter some of the side effects of high levels of greenhouse gases in the atmosphere.

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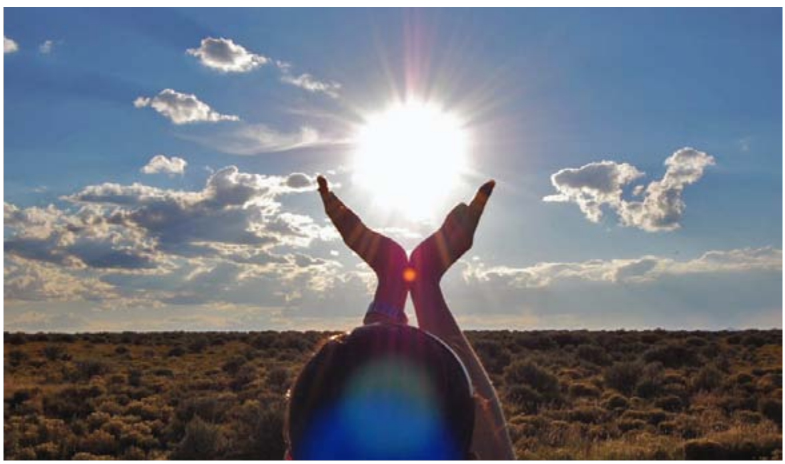

SRM (blocking or reflecting sunlight) could cause significant environmental harm, including releasing additional greenhouse gases into the atmosphere, changing weather patterns and reducing rainfall, damaging the ozone layer, diminishing biodiversity, reducing the effectiveness of solar cells as well as causing sudden and dramatic climatic changes if deployment is stopped, either intentionally or unintentionally. (See Case Study 2 below for more information.) SRM will not address the problem of atmospheric greenhouse gases or ocean acidification. Political uncertainties are implied by the technical uncertainties, but are even more daunting: Who should control the Earth's thermostat? Who will make the decision to deploy? What are the implications of one country, corporation, or even a billionaire deciding unilaterally – or as part of a 'coalition of the willing' – to pursue deployment?

Geoengineering involving SRM technologies

Artificial volcanoes: Continuously spraying particles (e.g., sulphur, titanium dioxide) into the stratosphere to increase reflection of incoming solar radiation; particles could be injected into the stratosphere by, for example, aeroplanes, artillery, hoses lifted by giant balloons.

Desert covering: Covering large expanses of desert with reflective materials.

Space sunshades: One suggestion describes launching trillions of small, free-flying spacecraft a million miles above the Earth to form a cylindrical 'cloud' 60,000 miles long to divert about 10% of sunlight away from the planet.

Arctic ice covering : Covering snowpack or glaciers in the Arctic with insulating material or a nanoscale film to reflect sunlight and prevent melting.

White roofs and pavements or mountaintop painting: Painting roofs and road surfaces white to reflect sunlight (low-tech geoengineering).

'Climate-ready' crops: Includes genetic engineering to increase albedo (reflectivity) as well as plans to engineer crops and trees to be drought, heat or saline resistant.

Space mirrors: Putting a superfine reflective mesh of aluminium between the Earth and sun.

Large scale land-use change/rainwater harvesting: Engineering large-scale changes in water movements in order to provoke cloud formation to reflect sunlight.

Carbon dioxide removal and sequestration

Carbon dioxide removal and sequestration are geoengineering technologies intended to take carbon dioxide out of the atmosphere after it has been released. Some of the technologies use mechanical devices; others modify the chemical balance in the oceans to stimulate increased uptake of CO_2, while other technologies manipulate species and ecosystems with the intent of creating 'carbon sinks'.

The duration and the safety of sequestration in land or sea (whether through biological or mechanical means) are mostly unknown; and many of these techniques require land- and/or ocean-use changes that will negatively affect poor and marginalised people. Sequestration technologies intended to manipulate organisms or ecosystems are likely to have unpredictable side effects. For the most part, these technologies are also energy-intensive. To date, there is no way to ensure safe and affordable long-term carbon sequestration.

Geoengineering technologies involving CO_2 removal and sequestration

Ocean fertilisation with iron or nitrogen: Adding nutrients to ocean water to stimulate the growth of phytoplankton in an attempt to promote carbon sequestration in deep sea

Biochar: Burning biomass through pyrolysis (i.e., low oxygen environments so carbon is not released) and burying the concentrated carbon in soil

Carbon-sucking machines or air capture and mineral sequestration or synthetic trees: Extracting CO_2 from the air by using liquid sodium hydroxide, which is converted to sodium carbonate, then extracting the carbon dioxide in solid form to be buried

Modifying ocean upwelling or downwelling: Using pipes to bring up nutrient-rich seawater to the surface to cool surface waters and enhance ocean sequestration of CO_2

'Enhanced weathering' / adding carbonate to the ocean: Increasing ocean alkalinity in order to increase carbon uptake

'Enhanced weathering' (terrestrial): Controlling levels of atmospheric CO_2 by spreading fine-powdered olivine (magnesium iron silicate) on farmland or forestland

Crop Residue Ocean Permanent Sequestration (CROPS): Storing carbon by dumping tree logs or other biomass into seawater

Genetically engineered algae and marine microbes: Engineering communities of synthetic microorganisms to sequester higher levels of carbon dioxide (in ocean communities or in closed ponds, or even to cover buildings)

Weather modification

The idea that humans can intentionally control the weather has a long history reaching back to indigenous rain dances and the lighting of fires. Since the 1830s, governments and private companies have attempted to apply technological know-how to increase or decrease precipitation or to restrain storms by altering landforms, burning forests and dropping chemicals into clouds – both for military and non-military purposes. As climate change brings more frequent extreme weather events ranging from drought to tropical storms, weather control is making a comeback. Weather modification is a classic 'end-of-pipe' geoengineering response that neither addresses the causes nor the mechanism of climate change,

So-called 'weather warfare' by the US government during the Vietnam War led to an international agreement to ban hostile uses of weather modification techniques.

but seeks only to alter its effects. Weather modification has also been advanced as an adaptation technology for climate change (for example, for protecting water flow for hydropower schemes).

Predicting the weather is difficult; proving the efficacy of weather interventions is even more difficult. Nonetheless, attempts to produce rain in one place have been regarded by neighbouring cities as rainfall 'theft', especially if crops fail in the aftermath of the weather intervention. If interventions such as altering the course of hurricanes become possible, extensive damage at another site may no longer be considered 'an act of God'. So-called 'weather warfare' by the US government during the Vietnam War (under the code name 'Operation Popeye') led to an international agreement to ban hostile uses of weather modification techniques (ENMOD treaty, see below). Since weather is complex and inherently transboundary, the line between what is a hostile or peaceful intervention may be difficult to determine.

Geoengineering technologies involving weather modification

Cloud seeding to increase precipitation: Spraying chemicals (usually silver iodide) into clouds to precipitate rain or snow – already practiced on a large scale in the United States and China, despite scepticism about effectiveness

Storm modification (e.g., redirecting or suppressing hurricanes): Attempting to prevent the formation of storms or affect their pathways

Defining geoengineering

Defining geoengineering is a political act. As new technological climate fixes are contemplated, definitions become more complex, contentious and consequential. For example, whether or not to include carbon capture and storage, biochar, or weather modification under the rubric of geoengineering is hotly disputed. At the same time, as governments and multilateral organisations begin to articulate positions on technological developments, they require more precise definitions. Anyone who has participated in international negotiations knows the long and tedious hours spent wrangling over definitions that can have far-reaching consequences when they are incorporated into international law or multilateral agreements.

ETC Group defines geoengineering as the intentional, large-scale technological manipulation of the Earth's systems, including systems related to climate.

Most definitions of geoengineering include a reference to intent (i.e., to combat climate change). But the laudable goal of combating climate change has no place in the definition of geoengineering, as it suggests that geoengineering technologies do, in fact, combat climate change. The consequence is giving the suite of planet-altering technologies a veneer of respectability and efficacy it has not earned.

There is also a move, particularly by scientists actively involved in geoengineering research, to get away from the term *geoengineering* altogether. They argue that the term is too vague or that other descriptors are better from the point of view of public relations. The scientists who gathered in Asilomar, California, in March 2010 to look at 'voluntary guidelines' for research, for example, not only studiously avoided the term geoengineering (the conference was on 'climate intervention'), but they also sought to rebrand 'solar radiation management' as 'climate intervention' and carbon dioxide removal as 'carbon remediation'. Furthermore, the statement by the Scientific Organizing Committee at the conclusion of the controversial meeting did not mention geoengineering (nor for that matter, the voluntary standards the meeting was convened to develop) (Climate Institute, 2010).

Different multilateral bodies may end up defining geoengineering differently. However, there is general agreement that the following elements be included in a definition of geoengineering:

Intent: Geoengineering is always deliberate (even if it may have unintended impacts). Unintentional harm to the global environment or climate from other activities (i.e., global warming) is thus excluded.

Scale: Geoengineering technologies are intended for global, or at least large-scale, deployment rather than local application.

Technology: Geoengineering is a high-technology approach: changing consumption patterns or adopting agroecological practices, for example, do not qualify, although either could have a noticeable impact on the climate.

Earth systems: Contemporary discussions about geoengineering almost always invoke the climate crisis (that is the main rationale for their deployment – 'desperate times call for desperate measures') but it is conceivable that geoengineering schemes could be employed to manage the Earth's hydrological cycle or nitrogen cycles in addition to the carbon cycle. While it may be useful to refer to the climate for descriptive purposes, it would be short sighted to think that climate change mitigation will be the sole purpose of these technologies, especially given the 'market opportunities' geoengineering may offer.

Beyond all these definitional elements, geoengineering is also a philosophy and a worldview coloured by a Western, male-dominated, technological paradigm. As Simon Terry of the Sustainability Council of New Zealand has pointed out, geoengineering contrasts sharply with the notion of stewardship: geoengineers see ecosystems as resources to be optimised or 'fixed' rather than systems to be protected and restored (Terry 2009). The *Encyclopaedia Britannica* defines engineering as 'the application of science to the optimum conversion of the resources of nature to the uses of humankind'; 'geo', of course, refers to the Earth. As Indian ecologist Vandana Shiva articulated recently: 'It's an engineering paradigm that created the fossil fuel age that gave us climate change... Geoengineering is trying to solve the problems in the same old mind-set of controlling nature' (*Democracy Now*, 2010).

How we got here: the mainstreaming of geoengineering

The US President's Science Advisory Committee suggested already in 1965 that reflective particles could be dispersed on tropical seas (at an annual cost of around US$500 million), which might also inhibit hurricane formation.

In a sense, geoengineering has always been 'on the table' as a possible response to climate change. As early as 1965, the US President's Science Advisory Committee warned in a report, *Restoring the Quality of Our Environment*, that CO_2 emissions were modifying the Earth's heat balance (Fleming, 2007: 13). 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' (Fleming 2007: 13). They suggested that reflective particles could be dispersed on tropical seas (at an annual cost of around US$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 and geoengineering, wryly notes, the very first official report on ways to address climate change 'failed to mention the most obvious option: reducing fossil fuel use' (Fleming, 2007: 57).

The notion of engineering the Earth's climate really took off in 2002 when Paul J. Crutzen – who won a Nobel Prize for pioneering work on the ozone layer and is a professor at the Max-Planck-Institute for

Chemistry in Mainz, Germany – offered grudging support for geoengineering in the journal *Nature*. Since we are living in the 'anthropocene' era in which humans are increasingly affecting the climate, Crutzen suggested, our future 'may well involve internationally accepted, large-scale geoengineering projects'(Crutzen 2002). The same year, Science published its own article arguing for geoengineering as a legitimate approach to combat climate change (Hoffert et al., 2007).

Crutzen willingly acknowledged that his was a risky proposition and insisted that it should be undertaken only if all else failed. He went on to add that the political will to do anything else seemed to have failed already.

By 2005, 40 years after the release of the Science Advisory Committee's report, everybody, including the sitting US president, was talking about global warming: scientists warned that the temperature rise on the Arctic ice cap and Siberian permafrost could 'tip' the planet into an environmental tailspin, and the US Congress agreed to study a bill that would establish a national 'Weather Modification Operations and Research Board.' The same year, another high-profile climatologist, Yuri Izrael, former vice-chair of the Intergovernmental Panel on Climate Change (IPCC) and head of the Moscow-based Institute of Global Climate and Ecology Studies, wrote to Russian president, Vladimir Putin, outlining a proposal to release 600,000 tonnes of sulphur aerosol into the atmosphere to take a few degrees off global temperatures.

Paul Crutzen returned to the debate in August 2006 when he wrote an 'editorial essay' in the journal *Climatic Change* calling for active research into the use of 'sub-micrometer'-sized sulphate-based aerosols to reflect sunlight in the stratosphere (Crutzen, 2006). Crutzen opined that high-altitude balloons and artillery cannons could be used to blast sulphur dioxide into the stratosphere, in effect, simulating a volcanic eruption.

The sulphur dioxide would convert to sulphate particles. The cost could run between US$25 billion and US$50 billion per year – a figure, he argued, that was well below the trillion dollars spent annually by the world's governments on defence. Crutzen noted that his cost estimates did not include the human cost of premature deaths from particulate pollution. Such tiny reflective particles could be resident in the air for two years. Crutzen willingly acknowledged that his was a risky proposition and insisted that it should be undertaken only if all else failed. He went on to add that the political will to do anything else seemed to have failed already.

An editorial in the same issue of *Climatic Change* by Ralph J. Cicerone, an atmospheric chemist and president of the US National Academies, also supported further research on Crutzen's geoengineering proposals (Cicerone 2006). The same year he told *The New York Times*, 'We should treat these ideas like any other research and get into the mind-set of taking them seriously' (Broad 2006).

By November 2006, NASA's Ames Research Center had convened an elite meeting of geoengineering advocates to explore options with Lowell Wood, who was then at the Lawrence Livermore National Laboratory, presiding. 'Mitigation is not happening and is not going to happen', the physicist reportedly told the group (Fleming, 2007). The time has come, he argued, for 'an intelligent elimination of undesired heat from the biosphere by technical ways and means' (Fleming 2007). According to Wood, his engineering approach would provide 'instant climatic gratification' (Fleming 2007). From that meeting came the beginnings of a campaign to secure funding for geoengineering research – requiring the field to gain respectability – and fast. Just three years later, geoengineering got a huge legitimacy boost from the UK's Royal Society when it published *Geoengineering the Climate: Science, governance and uncertainty*, which recommended that public funding be dedicated to geoengineering research (Royal Society, 2009).

The failure to reach a meaningful multilateral consensus on emissions reduction at the UNFCCC's COP-15 in Copenhagen (2009) – despite the largest mobilisation for climate justice in history – offered geoengineers a more popular public platform. As delegates were just beginning to check out of their hotels, Nathan Myhrvold gave a 30-minute interview on CNN, extolling the virtues of putting sulphate particles into the stratosphere as a solution to global warming; he explained how a 25-km hose held up by balloons could deliver the particles to the right place to reflect sunlight away from the Earth (GPS Podcast, 2009).

Myhrvold is a former Chief Technology Officer at Microsoft and now runs Intellectual Ventures Management, LLC, which holds patents on geoengineering technologies. Prominent geoengineering scientists Ken Caldeira and John Latham are listed among the firm's senior inventors, whom Intellectual Ventures supports with funding and business expertise. The firm files 500-600 patent applications every year. (Ken Caldeira and Harvard's David Keith jointly manage the 'Fund for Innovative Climate and Energy Research' bankrolled by Bill Gates. Since 2007 the Fund has given out US$4.6 million in research grants.)

The Lomborg Manoeuvre: Once climate-change denier, now geoengineering devotee

An odd effect of geoengineering's mainstreaming has been an alignment of positions that were previously diametrically opposed. While some long-time climate scientists such as Paul Crutzen and Ken Caldeira claim to have only gradually and reluctantly embraced geoengineering out of a fear of global warming's devastating effects, a new and powerful lobby for geoengineering has emerged in recent years, made up of people whose motivation has never been concern for the environment or for the world's poorest people.

The 'Lomborg manoeuvre' – switching from opposing action on climate change to supporting the most extreme action on climate change – is now seemingly de rigueur among industrial apologists, former climate change sceptics and 'deniers'.

In June 2008, Newt Gingrich, former Speaker of the House in the US Congress, sent a letter to hundreds of thousands of Americans urging them to oppose proposed legislation to address global warming. Gingrich argued for geoengineering the atmosphere with sulphates as a better option to fight climate change. 'Geoengineering holds forth the promise of addressing global warming concerns for just a few billion dollars a year', wrote Gingrich (Gingrich, 2008). 'Instead of penalizing ordinary Americans, we would have an option to address global warming by rewarding scientific innovation... Bring on the American Ingenuity. Stop the green pig' (Gingrich, 2008).

Emil Jupin

Bjørn Lomborg is best known as the self-styled and controversial 'sceptical environmentalist' who has consistently downplayed the seriousness of climate change.

Gingrich is a recent presidential hopeful and senior fellow at the American Enterprise Institute (AEI) – a neoconservative think tank promoting free enterprise and limited government – closely associated with the recent Bush administration. AEI's own geoengineering project was led by Lee Lane, an advisor to the Bush administration, now at the Hudson Institute, another neoconservative think tank. In 2009, Lane and co-author J. Eric Bickel published 'An Analysis of Climate Engineering as a Response to Climate Change', a report advocating the addition of geoengineering to existing responses to climate change on the basis of a cost-benefit analysis. Lane and Bickel claimed spraying seawater into clouds might be able to fix climate change and thereby add US$20 trillion to the global economy.

The report was published and widely broadcast by Bjørn Lomborg's Copenhagen Consensus Center (CCC). Lomborg is best known as the self-styled and controversial 'sceptical environmentalist' who has consistently downplayed the seriousness of climate change. Lomborg is now using his CCC and high media profile to push for geoengineering not as 'Plan B', but as 'Plan A' – the preferred route to cooling the planet. In May 2012, the CCC published a new paper by Lane and Bickel, *Climate Change: Climate Engineering Research*, in which they 'roughly estimate' that the benefit-to-cost ratio of research and development of SRM technologies is 'on the order of 1000 to 1' (Bickel and Lane, 2012: 3).

The 'Lomborg manoeuvre' – switching from opposing action on climate change to supporting the most extreme action on climate change – is now seemingly de rigueur among industrial apologists, former climate change sceptics and 'deniers', especially in the United States. Besides Lane at the Hudson Institute and Gingrich at AEI, political operators at the Cato Institute, the Thomas Jefferson Institute, the Hoover Institution, the Competitive Enterprise Institute, the International Policy Network and elsewhere have professed their faith in the geoengineering gospel. Geoengineering has been a mainstay of discussion for several years now at the Heartland Institute's International Conference on Climate Change, dubbed the annual 'climate deniers jamboree'. The *New York Times* recently described the Heartland Institute 'as the primary American organization pushing climate change skepticism' (Gillis, 2012).

For those who previously doubted (or still do doubt) the science of anthropogenic global warming, the geoengineering approach shifts the discussion from reducing emissions to end-of-pipe 'solutions'. Once geoengineering is an option, there is less need to bicker about who put the carbon dioxide in the atmosphere (and less need to ask them to stop). If we have the means to suck up greenhouse gases or turn down the thermostat, emitters can, in principle, continue unabated.

Geoengineering, governance and multilateral fora

As geoengineering gains prominence and respectability in some scientific and policy discussions emanating from the North, the issue of governance has come to the fore. For geoengineering advocates, this is both welcome and worrisome. On the one hand, they fear restrictive or limiting policy decisions; on the other hand, they recognise that the existence of some kind of governance framework will facilitate development; their goal, then, is to influence the shape of the frameworks to best serve their needs. The dominant frame in which experts talk about geoengineering governance is voluntary: 'codes of conduct', 'standards', 'guidelines' and 'bottom-up approaches' are offered; 'legally binding' is generally taboo.

The years since the 2009 climate negotiations in Copenhagen have been critical for the discussion of geoengineering, in general, and of governance in particular. The collapse of the Copenhagen negotiations offered advocates of geoengineering a political opportunity to advance their agenda. Building on the credibility boost obtained by the UK Royal Society's 2009 report, they undertook to debate the question of governance publicly.

Governance determines who has power, who makes decisions, how other players make their voices heard, and how account is rendered.

Often, it is the scientists and institutions engaged in the geoengineering projects that are among the most anxious to put in place some structure of governance, since the absence of any governance regime means delayed funding, missed experimentation opportunities, a wary public and the inability to bring techno-fixes to market.

A meaningful governance discussion on geoengineering must be:

- International, transparent and accountable, where all governments can freely participate in a democratic manner, open to public scrutiny and the full participation of civil society organisations, indigenous peoples and social movements (especially those most directly affected by climate change), and that is accountable to the United Nations in its outcomes.[1]
- Free from corporate influence so that private interests cannot use their power to determine outcomes or to promote schemes that serve their interests.
- Respectful of existing international laws including those protecting peace and security, human rights, biodiversity, national sovereignty, and those prohibiting hostile acts of weather modification.
- Mindful of concomitant crises, especially hunger, poverty, loss of biological diversity, ecosystem destruction and ocean acidification.
- Guided by the principle of precaution and cognisant that neither the seriousness of the climate crisis nor a lack of scientific knowledge can be used to justify experimentation.

UN Framework Convention on Climate Change (UNFCCC): While the word *geoengineering* does not appear in the texts of the Convention or the Kyoto Protocol, it will likely make its debut in the work of the UNFCCC's Technology Mechanism, the establishment of which was agreed at the Cancun Conference of the Parties (COP) in late 2010 (Decision 1/CP.16 para 117) (UNFCCC, 2011: 19).[2]

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1 Not surprisingly, the logic of global participation to address governance issues is not universally accepted. Lee Lane has written, 'Managing [climate engineering] will entail many choices, and, as knowledge grows, the system may need frequent fine-tuning. Expectations and interests will differ by region, and bargaining costs may be high. With too many players, the process could easily grind to a halt...To be sure, control by the major powers will likely be imperfect, but, then again, locking the world into a CE stalemate pending arrival of global-scale Periclean democracy seems to be an even less appealing option' (Lane, 2010).

2 The IPCC held an expert meeting on geoengineering in 2011, which included all three of its Working Groups. The IPCC is expected to include geoengineering for the first time in its next Assessment Report (AR5), due by the end of 2014. As the IPCC's role is to provide scientific and technical information to the UNFCCC, it is only a matter of time before geoengineering makes an official appearance in negotiating texts at the Convention.

The Mechanism consists of a Technology Executive Committee and a Climate Technology Centre and Network and 'is expected to facilitate the implementation of enhanced action on technology development and transfer in order to support action on mitigation and adaptation to climate change' (UNFCCC, undated).

The UNFCCC is notoriously optimistic vis-à-vis 'advanced and innovative' climate technologies. Its fact sheet, 'Why technology is so important', reflects that optimism: 'Environmentally sound technologies are able to provide win-win solutions, allowing global economic growth and climate change mitigation to proceed hand in hand' (UNFCCC, 2009: 1).[3] In other words, technologies will allow us to continue on our current trajectory of increasing consumption and production without suffering consequences. Criteria for environmental soundness have not been established. Implicit in the faith in technology is a concomitant faith in the private sector: 'The role of business as a source of solutions on global climate change is universally recognized' (UNFCCC, 2009:1). The lure of technological quick fixes and the hope of easily available private sector investments are certainly attractive to governments not wanting to risk inconveniencing their electorate or offend Industry. The role of the private sector is, however, a contentious issue.

The UNFCCC emphasises the importance of 'enabling environments' for technology transfer, covering a wide array of issues, including intellectual property rights (IPRs), incentive mechanisms, and the removal of barriers for technology development and transfer. IPRs are particularly hotly contested due to wide disagreement about whether they promote or inhibit innovations in climate technologies. At the Cancun COP, the United States effectively blocked all mention of IPRs, including the option to continue discussing the issue under the UNFCCC.

Geoengineering techniques that 'manage solar radiation' (SRM) could also be implied in the temperature reduction targets adopted by states, for example. Already, some geoengineering advocates (notably ocean fertilisation and biochar advocates) have tried to use the Convention to get unproven technologies accredited under its Clean Development

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3 See also Article 10(c) of the Kyoto Protocol: '[All Parties shall...] cooperate in the promotion of effective modalities for the development, application and diffusion of, and take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies, know-how, practices and processes pertinent to climate change, in particular to developing countries, including the formulation of policies and programmes for the effective transfer of environmentally sound technologies that are publicly owned or in the public domain and the creation of an enabling environment for the private sector, to promote and enhance the transfer of, and access to, environmentally sound technologies...'

Mechanism (CDM), which allows countries with emissions-reduction commitments to shift their obligation to an emissions-reduction project in a developing country. If a technology as potentially harmful as ocean fertilisation becomes accredited under the CDM, for example, the profits to be made by using the oceans as ostensible 'carbon sinks' could quickly subordinate the other vital functions they serve, notably – but certainly not uniquely – as food sources.

Convention on Biological Diversity (CBD): So far, the most nuanced and multifaceted multilateral discussion of geoengineering has been at the Convention on Biological Diversity. In 2008, the CBD was ahead of the curve when it adopted a moratorium on ocean fertilisation. At COP 10 in 2010 (Nagoya, Japan), the CBD's 193 Parties expanded that moratorium to cover all geoengineering technologies,[4] marking geoengineering's 'definite coming of age', according to *The Economist* (2010). While carving out an exemption for small-scale scientific experiments in controlled settings within national jurisdiction, the CBD decision invoked the precautionary approach to prohibit geoengineering activities until social, economic and environmental impacts have been considered and a proper regulatory mechanism is in place. The CBD has almost universal state membership – the United States, Andorra and the Vatican are the only UN members that have not ratified the treaty – and has a mandate not only to consider biodiversity, but also to involve local communities and indigenous peoples in its processes. A peer-reviewed study (with inputs from geoengineering advocates and those opposing geoengineering) on the impacts of geoengineering on biodiversity was circulated at the 16th meeting of the CBD's Scientific Body (SBSTTA) in April/May 2012 in Montreal. In its report of the Montreal meeting, the SBSTTA recommended that the CBD's COP reaffirm the de facto moratorium on geoengineering activities and call for updated/expanded reports on geoengineering's potential impacts on biodiversity and on the views of indigenous and local communities when it meets in Hyderabad, India, for its 11th meeting (October 2012) (CBD, 2012).

4 See paragraph 8(w) of CBD COP Decision X/33: 'Ensure, in line and consistent with decision IX/16 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.'

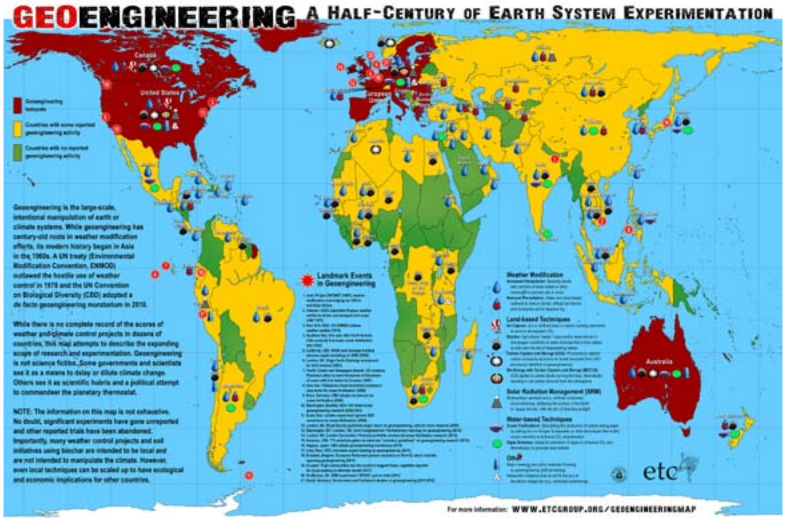
Rio+20: The outcome of Rio+20 (June 2012), a largely underwhelming document called *The Future We Want*, did, however, include text that could open up space to effectively evaluate geoengineering (CSD, 2012). There is a paragraph acknowledging the importance of global-to-local technology assessment especially in light of the possible deployment of new technologies with unintended consequences (CSD, 2012: para 275)[5] and a paragraph requesting the Secretary General to make recommendations regarding the establishment of a technology facilitation mechanism to the 67th Session of the UN General Assembly, which begins September 2012 (CSD, 2012: para 273).[6] More surprising in a document that failed to tackle issues with specificity and decisiveness, the document waved a bright red flag at ocean fertilisation, noting its 'potential environmental impacts' and resolving to continue addressing ocean fertilsation with 'utmost caution…consistent with the precautionary approach' (CSD, 2012: para 167).

ETC Group has emphasised the need for effective technology evaluation at the UN level for more than a decade. We have envisioned a new International Convention for the Evaluation of New Technologies (ETC Group, 2010), and will continue to advocate for a sound, full, timely, transparent and participatory process that supports societal understanding, encourages scientific discovery and facilitates equitable benefit-sharing.

ETC Group believes that developing countries will welcome early warning, open assessment and facilitated access. Developed countries – including their scientific organisations, industry, and governments – will welcome an end to unpredictability and societal distrust and the establishment of a generalised, non-crisis approach to technology diffusion. Civil society will welcome a transparent and participatory process with both early listening /warning and technology conservation/diversification potential.

5 'We recognize the importance of strengthening international, regional and national capacities in research and technology assessment, especially in view of the rapid development and possible deployment of new technologies that may also have unintended negative impacts, in particular on biodiversity and health, or other unforeseen consequences.'

6 Of course, geoengineering is not the only technology field in urgent need of assessment. Elsewhere, ETC Group and others have argued for the need for inclusive and participatory assessments of the health, environmental and socio-economic impacts of other emerging technologies, including nanotechnology, synthetic biology and technologies intended to augment human performance (ETC Group 2006; ETC Group 2007; Wolbring 2009). Equally important, the UN cannot and should not do it alone. ETC Group is working with partners to establish dynamic civil society structures at the regional and inter-regional level that could serve as Technology Observation Platforms ('TOPs') with an independent monitoring and assessment capacity to accompany intergovernmental processes.



As part of its engagement with the Rio+20 process and to highlight the need for technology evaluation, ETC Group published a world map of geoengineering. While there is no complete record of the scores of weather and climate control projects in dozens of countries, this map is the first attempt to document the expanding scope of research and experimentation. Almost 300 geoengineering projects/experiments, belonging to 10 different types of climate-altering technologies, are represented on the map. A high-resolution version of the map can be downloaded at http://www.etcgroup.org/content/world-geoengineering (ETC Group, 2012).

London Convention/London Protocol: The London Convention/Protocol is a treaty of the International Maritime Organization to prevent marine pollution via ocean dumping; its consideration of geoengineering is therefore limited to those technologies directly involving activities in the ocean. The Convention/Protocol was quick to take up the issue of ocean fertilisation and resolved at its 2008 meeting that its Scientific Groups would establish an assessment framework to identify legitimate scientific research on ocean fertilisation, noting the de facto moratorium on ocean fertilisation agreed at the CBD earlier in the year. The Assessment Framework was adopted at their 2010 meeting. Eighty-seven states are Parties to the Convention; 42 are Parties to the Protocol.

Intellectual property

Adding to the controversy surrounding geoengineering are the critical issues of ownership and control. The politics of patents has always been a divisive issue in various international policy fora.

In the UNFCCC, governments from the global South generally advocate enhanced mechanisms for transfer of useful technologies, including significant financing from developed countries, arguing that existing intellectual property (IP) regimes are a barrier to accessing the technologies necessary to mitigate and adapt to climate change. The North advocates – and generally gets – strong protection of intellectual property, arguing that high profits derived from IP drives innovation and, eventually, the transfer of technologies.

With regard to climate-related technologies, restricting the diffusion of technologies by way of a 20-year monopoly is clearly counterproductive to enabling urgent action. In this sphere IP therefore enables patent holders to levy lucrative licensing and transfer fees or to press for even more favourable 'enabling environments' (for example, liberalised foreign investment and strong domestic IP regimes). As with other high-tech industries, the profits to be made from licensing patented geoengineering technologies becomes a driver for governments to support geoengineering development, research and diffusion – even when in conflict with safety, efficacy or cultural values.

If geoengineering techniques move toward actual deployment, the existence of patents held by individuals and private companies could mean that decisions over the climate- commons will be effectively handed over to the private sector. Indeed geoengineers are already claiming that their patents give them extended commercial rights over the commons in which they operate. In one of several patents assigned to Professor Ian S. F. Jones, founder and chief executive of Ocean Nourishment Corporation, describes how his method of ocean fertilisation will increase fish populations and the patent claims ownership of the fish subsequently harvested from a fertilised patch of ocean (Jones 2008: claim 15).

Some geoengineering patents also effectively privatise indigenous and traditional knowledge, most clearly demonstrable in the area of biochar. Before the turn of the first millennium, the technique of burying charcoal in soil was widely practised by communities throughout the Amazonian Basin, where it was known as *terra preta*. This technology is now the subject of several patent applications.[7]

As with other technology innovators (in software, biotechnology, robotics), some geoengineers are considering forgoing their intellectual property claims in order to speed up development of the technology. CQuestrate, a geoengineering firm in the UK with investments from Shell Research, is developing a technique to add lime to oceans. The company is a self-described 'open source geoengineering company' and declares it will not seek any patents on the technology that results.

Why is geoengineering unacceptable?

» **It can't be tested:** No experimental phase is possible – in order to have a noticeable impact on the climate, geoengineering must be deployed on a massive scale. 'Experiments' or 'field trials' are actually equivalent to deployment in the real world because small-scale tests do not deliver the data on climate effects. For people and biodiversity, impacts would likely be massive as well as immediate and possibly irreversible.

7 There are several examples provided in *Geopiracy: The Case Against Geoengineering* (ETC Group, 2010: 31-32).

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- **It is unequal:** OECD governments and powerful corporations (who have denied or ignored climate change and its impact on biodiversity for decades but are responsible, historically, for most greenhouse gas emissions) are the ones with the budgets and the technology to execute this gamble with Gaia. There is no reason to trust that they will have the interests of more vulnerable states or peoples in mind.
- **It is unilateral:** Although all geoengineering proposals run into tens of billions of dollars, for rich nations and billionaires, they could be considered relatively cheap (and simple) to deploy. The capacity to act will be within the hands of those who possess the technology (individuals, corporations, states) in the next few years. It is urgent that multilateral measures are taken to ban any unilateral attempts to manipulate Earth ecosystems.
- **It is risky and unpredictable:** The side effects of geoengineered interventions are unknown. Geoengineering could easily have unintended consequences due to any number of factors: mechanical failure, human error, inadequate understanding of ecosystems and biodiversity and the Earth's climate, unforeseen natural phenomena, irreversibility, or funding lapses.
- **It violates treaties:** Many geoengineering techniques have latent military purposes and their deployment would violate the UN Environmental Modification Treaty (ENMOD), which prohibits the hostile use of environmental modification.
- **It is the perfect excuse:** Geoengineering offers governments an alternative to reducing emissions and protecting biodiversity. Geoengineering research is often seen as a way to 'buy time', but it also gives governments justification to delay compensation for damage caused by climate change and to avoid taking action on emissions reduction.
- **It commodifies our climate and raises the spectre of climate profiteering:** Those who think they have a planetary fix for the climate crisis are already flooding patent offices with patent applications. Should a 'Plan B' ever be agreed upon, the prospect of it being privately controlled is terrifying. Serious planet-altering technologies should never be undertaken for commercial profit. If geoengineering is actually a climate emergency back-up plan, then it should not be eligible for carbon credits under the Clean Development Mechanism or any other offset system.

Conclusions

Geoengineering offers a technological 'fix' to the governments and industries that created the climate crisis in the first place and then failed to adopt the policies that would mitigate its damage. The consequences of high-risk geoengineering activities, including real world experimentation, are global. The world's peoples and governments must debate these consequences before any action outside the laboratory can be countenanced. No unilateral initiative to experiment with these technologies can be considered legally, practically or morally acceptable.

The Geoclique[8] prefers to publicly discuss research about geoengineering rather than discuss geoengineering itself. Leading spokespersons for the scientific community go to great lengths to insist that advocating for more research is a responsible stance and entirely separate from advocating for deployment. This view is at best naïve and at worst deliberately misleading. Scientists have their careers, professional reputations and, often, financial interests at stake, and they want more funding, more institutional support and a permissive regulatory environment. Also at play are carbon markets, corporate interests, patents, profits, institutional reputations, egos and scientific hubris. All this perverts research and privileges some options while others are left behind. The dollars that are spent on geoengineering research will necessarily be diverted from elsewhere, including from funds for adaptation, already hopelessly inadequate.

We cannot be content with arguments for how geoengineering schemes could theoretically work in their best-case scenarios, and ignore the power politics and slippery slopes that inevitably come with them. Ensuring that precautionary policies for governance have been adopted is insufficient because once the discussion has reached that stage, the genie is out of the bottle. It may sound reasonable – or even responsible – to keep all options 'on the table' and prepare for Plan B, but Plan B inevitably makes its mark on Plan A. Already in 2012, Plans A and B are no longer discreet, and we are observing the tendencies towards step-by-step legitimation and, in some quarters, acceptance of geoengineering.

For this reason, the argument about a 'slippery slope' of geoengineering warrants serious consideration. In light of the power games at play in the UNFCCC negotiations as well as the refusal of the Annex 1 countries, in particular, to commit to meaningful emissions reductions, even a moderate stance on geoengineering is problematic. The argument that geoengineering buys time (and money) until the transition to a low-carbon economy takes place is likely to have the opposite effect: it will hold back the momentum for change. Such delays in mitigation will increase the overall cost for society. Perhaps the major source of hope lies in the inescapable fact that to deal successfully with climate change, far-reaching change is necessary when it comes to our economic and development models. Either we do that, or we perish. Wishful thinking on geoengineering threatens that political driving force and further work on geoengineering may mean we close the window of opportunity that still exists.

8 Geoclique refers to the group of scientists, retirees and hobbyists actively engaged in the discussion (Kintisch, 2010: 8).

Case Study 1: Ocean fertilisation

> Engaging in experiments with the explicit purpose of assessing iron fertilisation for geoengineering is both unnecessary and potentially counterproductive, because it diverts scientific resources and encourages what we see as inappropriate commercial interest in the scheme (Strong et al., 2009a)

The theory

Oceans play a key role in regulating the world's climate. Phytoplankton (microorganisms that dwell on the surface of the ocean), collectively account for half of the carbon dioxide absorbed annually from the Earth's atmosphere by plants, despite their minuscule size. Through the process of photosynthesis, plankton capture carbon and sunlight for growth, and release oxygen into the atmosphere. The world's oceans have already absorbed about one-third of all the carbon dioxide humans have generated over the last 200 years. According to NASA, about 90 per cent of the world's total carbon content has settled to the bottom of the ocean, mostly in the form of dead biomass (Herring, 1999).

Proponents of ocean fertilisation posit that dumping 'nutrients' (generally iron, nitrogen or phosphorous) in waters identified as 'high nutrient/low chlorophyll' (HNLC) – where there are low concentrations of phytoplankton due to the absence of one nutrient – will spur the growth of phytoplankton. Since phytoplankton use CO_2 for photosynthesis, the idea is that increasing the population of phytoplankton will increase CO_2 absorption. They argue that when individual phytoplankton die (the lifespan of phytoplankton is short – a few days at most), they will fall to the ocean floor, leading to the long-term sequestration of carbon at the deeper levels of the sea.

The goal of commercial ocean fertilisation is to profit from selling carbon credits or offsets for the sequestered CO_2 through voluntary or regulated carbon markets.

Phytoplankton populations in the world's oceans are declining as a result of climate change and warmer water temperatures. The amount of iron that is naturally deposited from atmospheric dust clouds into the global oceans (providing nutrients for phytoplankton) has also decreased dramatically in recent decades. Advocates of iron fertilisation schemes believe that iron is the missing nutrient that will restore phytoplankton and sequester 2–3 billion extra tonnes of carbon dioxide every year – roughly one-third to one-half of global industry and automobile emissions. Some regions of the ocean (especially near the Arctic and Antarctic circles) are

Jurvetson

Each 'correction' to ocean water composition could have unintended effects.

nutrient-rich but anaemic – they lack sufficient iron to stimulate plankton growth. With the addition of iron in these presumably otherwise healthy zones, scientists hope to increase plankton growth, thereby increasing the absorption of CO_2. However, US and Canadian scientists writing in the journal *Science* point out, 'the oceans' food webs and biogeochemical cycles would be altered in unintended ways' (Chisholm et al., 2009). They warn that if carbon-trading schemes make it profitable for companies to engage in ocean fertilisation, 'the cumulative effects of many such implementations would result in large-scale consequences – a classic "tragedy of the commons"' (Chisholm et al., 2009). Others note that iron may not be the ocean's only nutrient 'deficiency' – researchers have identified silicate as a crucial component in carbon export, for example – but each 'correction' to ocean water composition could have unintended effects.

Who's involved?

There are both commercial and scientific ventures involved in ocean fertilisation and at least 13 experiments have been carried out in the world's oceans over the past 20 years (ETC Group, 2012). A 2007 experiment near the Galapagos Islands by US start-up Planktos, Inc. was stopped because of an international civil society campaign (ETC Group, 2007). The company was already selling carbon offsets on-line and the company's CEO acknowledged that its ocean fertilisation activities were as much a 'business experiment' as a 'science experiment'. Climos, another US start-up in the field, is still operational. The CEO of Climos has proposed a 'code of conduct' for ocean fertilisation experiments to 'find effective ways for the science, business and carbon market communities to collaborate'. The Ocean Nourishment Corporation, an Australian company run by Ian S. F. Jones with ties to the University of Sydney, had plans to dump urea (nitrogen) into the Sulu Sea but was stopped by the Filipino government in 2007, after over 500 civil society organisations campaigned against the plan (Keim, 2007). The science of ocean fertilisation is increasingly discredited, getting bad press from everyone from the Royal Society to *Nature* to Rio+20.

The 193 Parties to the Convention on Biological Diversity adopted a de facto moratorium on ocean fertilisation in May 2008 and then commissioned a synthesis report of scientific research on the impact of ocean fertilisation on biodiversity. The report emphasised the lack of knowledge about the role of oceans in the global carbon cycle and the difficulty in establishing reliable baselines to test efficacy, in addition to warning about the potential impacts of even small-scale experiments and of commercial ocean fertilisation as a whole. Elsewhere, prominent ocean scientists have explained in detail that 'we know enough about ocean fertilisation to say that it should not be considered further as a means to mitigate climate change', although they express interest in further research that may involve the addition of nutrients to the ocean in order to understand better marine ecological and biogeochemical processes (Strong et al., 2009b).

What's wrong with ocean fertilisation?

Phytoplankton are the foundation of the marine food chain. Iron may well stimulate the growth of algae blooms but their potential to capture and eliminate any significant amount of carbon is unproven. The list of potential side effects is long:

» Changes in marine food webs: Artificial plankton production may lead to changes in marine ecosystems at the base of the food chain, of particular concern when ocean ecosystems are already fragile and under stress.

» Reduced productivity in other areas: Iron-induced blooms may consume and deplete other vital nutrients such that areas down-current from the fertilised area could suffer reduced plankton productivity and carbon fixation.

» Some scientists have raised concerns that iron fertilisation could in turn deplete oxygen levels at deeper levels of the ocean.

» Artificially elevated nutrient levels could give rise to harmful algal blooms that produce toxins associated with shellfish poisoning, fatal to humans.

» The production of dimethyl-sulphide (DMS), methane, nitrous oxide and volatile methyl halides can alter weather patterns unpredictably, cause ozone depletion and open a Pandora's box of impacts on atmospheric chemistry and global climate.

» Ocean acidification could be exacerbated.

» Coral reefs can be dramatically affected by tiny increases in nutrient levels, especially nitrogen, potentially provoking the growth of toxic dinoflagellates.

» Devastating impacts on the livelihoods of people who depend on healthy marine systems, most notably fisher folk.

The 1991 eruption of Mount Pinatubo in the Philippines spewed 20 million tonnes of sulphur dioxide into the stratosphere and the entire planet cooled by 0.4–0.5°C.

Case Study 2: Artificial volcanoes – putting reflective particles in the stratosphere

The theory

This geoengineering technique falls under the category of solar radiation management (SRM) and aims to reduce the amount of sunlight entering the Earth's atmosphere by putting tiny, reflective particles into the stratosphere. The 1991 eruption of Mount Pinatubo in the Philippines spewed 20 million tonnes of sulphur dioxide into the stratosphere and the entire planet cooled by 0.4–0.5°C. Although the idea of artificial volcanoes was first proposed in 1977, the concept has undergone refinement in recent years. Scientists estimate that a 2 per cent reduction of sunlight could negate the temperature rise resulting from of a doubling of atmospheric CO_2. Advocates envisage executing this technique regionally, most likely over the Arctic, in order to stall the disappearance of, or even to replenish, ice. The particles – sulphates are most commonly suggested – could be blasted by jets, fire hoses, rockets or chimneys. (More recently, it has been suggested that levitating manufactured nanoparticles could be used to the same end. Ideally, the particles would have a radius of approximately 5 micrometres (μm) with 50 nanometres (nm) thickness; 100,000,000kg of particles would need to be lofted above the stratosphere annually, assuming the particles would last 10 years (Keith, 2010b).

'Plan B' par excellence, artificial volcanic eruptions are promoted as an 'emergency' measure that would bring quick and inexpensive results. While some prominent scientists are anxious to move ahead with testing, others, including Rutgers professor Alan Robock, have argued that solar radiation management cannot be tested without full-scale implementation because it is too difficult to distinguish between the effects of small-scale experiments and climatic fluctuations that occur naturally (Robock, 2008).

Who's involved?

Blasting particles into the atmosphere is now the ascendant geoengineering approach (Blackstock et al., 2009: 13). The US Defense Advanced Research Projects Agency (DARPA) has looked at possible methods for distributing the particles and NASA has researched the impacts of aerosols on climate change.

In 2009, the UK Royal Society, along with its partners, the Environmental Defense Fund and the TWAS – the Academy of Sciences for the Developing World (Italy) – announced the SRM Governance Initiative, which aims to 'produce clear recommendation for the governance of geoengineering research'. The project is funded by, amongst others, the Carbon War Room, which defines its mission as harnessing 'the power of entrepreneurs to implement market-driven solutions to climate change'. Bill Gates has also provided the Initiative with funds.

More recently, controversy arose around the proposed UK Stratospheric Particle Injection for Climate Engineering (SPICE) experiment. The project involves four universities, three research councils and several government departments along with the private company, Marshall Aerospace. SPICE researchers intended to execute a pilot experiment blasting water into the sky with the help of a 1km hose and a giant balloon in order to evaluate the technology for possible larger-scale release of sulphur into the stratosphere. More than 70 civil society organisations signed an open letter asking the UK government to cancel the experiment (ETC Group, 2011); the field experiment was postponed for six months and finally cancelled in May 2012 (Hands Off Mother Earth, 2012). The Principal Investigator cited governance issues, including potential conflict-of-interest, as the principal reasons for cancelling the field trial (2012).

What's wrong with artificial volcanoes?

Slowing down or stopping the rate of warming via SRM does nothing to change the levels of CO_2 in the atmosphere, so some symptoms are addressed but not the causes. Even advocates admit that injecting particles into the stratosphere has unknown impacts, and that climate models cannot predict those impacts; nonetheless, research focusing on sulphate injections suggests (Robock, 2009):

» Impacts could be very different regionally, and several models show risk of increased drought over vast stretches of Africa, Asia and Amazonia.

» There is a fundamental trade-off between average global temperature stability and regional precipitation patterns, with one study showing that, if this technology were adopted, Northern countries and Southern countries would not agree on the amount of sulphate to be pumped into the stratosphere because of the different impacts.

» There will be damage to the ozone as sulphate particles in the stratosphere provide additional surfaces for chlorinated gases such as CFCs (chlorofluorocarbons) and HFCs (hydrofluorocarbons) to react.

» The ability to target particles in the specific areas where sunlight needs to be reduced (i.e., Arctic or Greenland) is highly speculative and it is likely the particles would diffuse.

» Preliminary modelling suggests a rapid rise in temperature if the programme were to be started and then stopped. Such a rapid rise would likely be more dangerous to life on Earth than a gradual rise.

» Reduced sunlight could undermine the amount of direct solar energy available (and the efficacy of photovoltaic cells) and disturb natural processes such as photosynthesis.

» It does nothing to address effects of ocean acidification from rising atmposheric CO leves

» What goes up still (usually) comes down. The tonnes of particles that would be regularly blasted into the stratosphere will find their way back to Earth again. All the issues related to environmental health and safety associated with particulate pollution, including novel manufactured nanoparticles, remain relevant for intentional polluting schemes.

» Geoengineering the stratosphere makes it easier for industry to continue its own atmospheric pollution.

References

Bickel, James Eric and Lee Lane (2012), 'Climate Change: Climate Engineering Research', Copenhagen Consensus Center (Challenge Paper), May.

Blackstock, J. J., D. S. Battisti, K. Caldeira, D. M Eardley, J. I. Katz,, D. W. Keith, A. A. N. Patrinos, D. P. Schrag, R. H. Socolow and S. E. Koonin, (2009), *Climate Engineering Responses to Climate Emergencies*, Novim, 2009. http://arxiv.org/pdf/0907.5140 (accessed 5 August 2012)

Broad, William J. (2006), 'How to Cool a Planet (Maybe)', *New York Times*, 27 June.

Chisholm, Sallie, Paul Falkowski and John Cullen (2001), 'Dis-Crediting Ocean Fertilization', *Science*, Vol. 294, No. 5541, 12 October, pp. 309-10.

Cicerone, Ralph J. (2006), 'Geoengineering: Encouraging Research and Overseeing Implementation', *Climatic Change*, Vol. 77, Nos. 3-4, August, pp. 221-226.

Climate Institute (2010), 'Conference Statement', Asilomar International Conference on Climate Intervention, Pacific Grove, CA (USA) 22-26 March 2010. http://www.climate.org/resources/climate-archives/conferences/asilomar/statement.html (accessed 4 August 2012)

CBD (2009), 'Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity', Convention on Biological Diversity, Technical Series No. 45, 2009. http://www.cbd.int/doc/publications/cbd-ts-45-en.pdf (accessed 5 August 2012).

CBD (2012), 'Report of the Sixteenth Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice', Convention on Biological Diversity, UNEP/CBD/SBSTTA/16/L.11. http://www.cbd.int/sbstta16/in-session/ (accessed 5 August 2012).

GPS Podcast (2009), *Fareed Zakaria interviews Nathan Myhrvold*, 20 December 2009 http://www.cnn.com/video/#/video/podcasts/fareedzakaria/site/2009/12/20/gps.podcast.12.20.cnn (accessed 4 August 2012).

Crutzen, Paul J. (2002), 'Geology of Mankind', *Nature*, No. 415, 3 January.

Crutzen, Paul J. (2006), 'Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?', *Climatic Change*, Vol. 77, Nos. 3-4, August, pp. 211-20.

CSD (2012), 'The Future We Want: Outcome Document Adopted at Rio+20', Commission on Sustainable Development, June. http://www.un.org/en/sustainablefuture/ (accessed 5 August 2012)

Democracy Now (2010), 'A Debate on Geoengineering: Vandana Shiva vs. Gwynne Dyer', video, 8 July. http://www.democracynow.org/2010/7/8/a_debate_on_geoengineering_vandana_shiva (accessed 4 August 2012)

Economist (The) (2010), 'Geoengineering Lift-off: Research into the possibility of engineering a better climate is progressing at an impressive rate – and meeting strong opposition', print edition 4 November 2010. http://www.economist.com/node/17414216 (accessed 5 August 2012)

ETC Group (2006), 'Nanotech Rx: Medical applications of Nano-scale technologies – What Impact on Marginalized communities?', September 2006 [Online] Available from: http://www.etcgroup.org/node/593 [Accessed 19 August 2012].

ETC Group (2007), *Extreme Genetic Engineering: An Introduction to Synthetic Biology*, January 2007 [Online] Available from: http://www.etcgroup.org/node/602 [Accessed 19 August 2012].

ETC Group (2010), *Geopiracy: The Case Against Geoengineering*, November 2010. http://www.etcgroup.org/content/geopiracy-case-against-geoengineering (accessed 4 August 2012)

ETC Group (2011), 'Open Letter About SPICE', 27 September. http://www.etcgroup.org/content/open-letter-about-spice-geoengineering-test (accessed 5 August 2012)

ETC Group (2012), 'Geoengineering World Map', June. http://www.etcgroup.org/content/world-geoengineering (accessed 5 August 2012)

Fleming, James R. (2007), 'The Climate Engineers', *Wilson Quarterly*, Spring.

Gillis, Justin (2012), 'Clouds' Effect on Climate Change Is Last Bastion for Dissenters', *New York Times*, 30 April 2012. http://www.nytimes.com/2012/05/01/science/earth/clouds-effect-on-climate-change-is-last-bastion-for-dissenters.html?_r=1 (accessed 5 August 2012)

Gingrich, Newt (2008), 'Can Geoengineering Address Concerns About Global Warming?', *Human Events*, 3 June. http://www.humanevents.com/2008/06/03/stop-the-green-pig-defeat-the-boxerwarnerlieberman-green-pork-bill-capping-american-jobs-and-trading-americas-future/ (accessed 4 August 2012)

Hands Off Mother Earth (2012), 'SPICE Boys Cancel Scheduled Appearance', 21 May. http://www.handsoffmotherearth.org/2012/05/spice-boys-cancel-scheduled-appearance/ (accessed 5 August 2012)

Herring, David (1999), 'What are phytoplankton?' NASA Earth Observatory. http://earthobservatory.nasa.gov/Features/Phytoplankton/ (accessed 5 August 2012).

Hoffert, M. I., K. Caldeira, G. Benford. et al. (2002), 'Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet', *Science*, Vol. 298, No. 5595, 1 November, pp. 981-7.

Institution of Mechanical Engineers (2009),'Climate Change: Have We Lost the Battle?', November. http://www.imeche.org/Libraries/Key_Themes/IMechE_MAG_Report.sflb.ashx (accessed 4 August 2012)

Jones, Ian S. F. (2008), 'Method for Attracting and Concentrating Fish', World Intellectual Property Organization, WO2008131485A1 (Patent Application).

Keim, Brandon (2007), 'Absorbing CO_2 by Dumping Urea Into Ocean Pisses Off Activists', *Wired*, 5 November. http://www.wired.com/wiredscience/2007/11/carbon-offset-c/ (accessed 5 August 2012)

Keith, David W. (2010a), 'Engineering the Planet', in S. Schneider, A. Rosencranz and M. Mastrandrea (eds), *Climate Change Science and Policy*, Washington, DC: Island Press.

Keith, David W. (2010b), 'Photophoretic levitation of engineered aerosols for geoengineering', *PNAS*, Vol. 107, No. 38, 21 September, pp. 16428-31 http://www.pnas.org/content/107/38/16428.abstract (accessed 5 August 2012).

Kintisch, Eli (2010), *Hack the Planet: Science's Best Hope – or Worst Nightmare – for Averting Climate Catastrophe*, Hoboken, NJ: John Wiley and Sons.

Lane, Lee (2010), 'Geoengineering Experiments Shouldn't Require Global Agreement', *AEIdeas*, Weblog, 30 March. http://www.aei-ideas.org/2010/03/geoengineering-experiments-shouldnt-require-global-agreement/ (accessed 5 August 2012).

Robock, Alan (2008), '20 reasons why geoengineering may be a bad idea', *Bulletin of Atomic Scientists*, Vol. 64, No. 2, pp. 14-18, 59. http://www.thebulletin.org/files/064002006_0.pdf (accessed 5 August 2012)

Royal Society (2009), *Geoengineering the climate: opportunities and uncertainties*, London: Royal Society.

Strong, Aaron, Sallie Chisholm, Charles Miller and John Cullen (2009), 'Ocean Fertilisation: time to move on, *Nature,* No. 461, 17 September, pp. 347-348.

Strong, Aaron, John Cullen and Sallie Chisholm (2009), 'Ocean Fertilization: Science, Policy and Commerce', *Oceanography,* Vol. 22, No. 3, September, pp. 236–61.

Terry, Simon (2009), '*Restoring the Atmosphere: Dangerous Climate Change and the New Governance Required', Sustainability Council,* August.

UNFCCC (undated), *Technology Mechanism* http://unfccc.int/ttclear/jsp/TechnologyMechanism.jsp (accessed 4 August 2012).

UNFCCC (2009), 'Fact Sheet: why technology is so important', June. http://unfccc.int/files/press/backgrounders/application/pdf/fact_sheet_on_technology.pdf (accessed 4 August 2012)

UNFCCC (2011), 'Decision 1/CP.16 The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention', FCCC/CP/2010/7/Add.1, 15 March 2011.

Wolbring, Gregor (2009), 'What next for the human species? Human performance enhancement, ableism and pluralism', *What Next? Volume II – The Case for Pluralism* (Development Dialogue, No. 52, August 2009) [Online] Available from: http://www.dhf.uu.se/publications/development-dialogue/what-next-volume-ii/ and http://www.whatnext.org/Publications/Volume_2/Volume_2_main.html [Accessed 19 August 2012].