Swedish Society for Nature Conservation

Report

Retooling the Planet?

– Climate Chaos in the Geoengineering Age

A report prepared by ETC Group

Climate Change

Key Issues

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Preface

With this report on risky technologies and geoengineering, the Swedish Society for Nature Conservation hopes to raise awareness and stimulate debate on an issue of major significance that few have yet considered.

As the climate crisis become ever more apparent, as new science indicates an even more serious situation, and as international climate negotiations prove disappointingly slow and unambitious, the attraction of quick, techno-fix solutions seems to be gaining ground. Geoengineering – the large-scale intentional modification of oceans, atmosphere and land to counter the effects of climate change – has over only a few years gone from the realm of science-fiction to now being discussed by established scientists, policy-makers and media. Still, most people, even those working on climate change, are largely unaware of what is going on.

This is also true for the Swedish Society for Nature Conservation. Geoengineering is an issue that has not been at the centre of our work so far. We do, however, realise that things are happening quickly and that we need to understand more, formulate positions and act, and do this sooner rather than later.

To help us understand the scientific, political and commercial context around geoengineering, we have asked the ETC Group, the civil society organisation that has probably followed the issue most intensively and over the longest period of time, to provide a report that shed light on this field, and that challenges ourselves as well as any other organisation or institution working on climate change. The analysis and recommendations presented in the report thus reflect the views of the authors.

This report is bound to shake us all. For those unaware of geoengineering it is an eye-opener. It also exposes the powers in play, the UN climate change negotiations context and the risks involved.

For an environmental organisation such as SSNC, issues of risk and precaution has alway been at the core of our work. So many environmental problems are due to a neglect of precaution. Instead of assessing new technologies carefully before commercialising and spreading them widely, both corporations and governments are all too willing to 'leap before they look' – with hard and painful consequences hitting back years later.

In this respect it is quite astounding that 'risk' and 'technology assessment' in general have so far not become strong, integral components in the negotiations around technology under the UN Framework Convention on Climate Change. We hope this report can help change this and also help mobilise action among both civil society organisations and governments to establish effective technology assessment frameworks. We also hope the report will stimulate more organisations to get actively involved in monitoring geoengineering as such. If not, the world runs a serious risk of choosing 'solutions' that turn out to be new global problems.

Svante Axelsson, Secretary-General, SSNC

Introduction

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, another notion is quickly gaining ground: that we can use geoengineering to purposefully intervene to correct the unintentional harm we've done to our climate.

Geoengineering is the intentional, large-scale intervention in the Earth's oceans, soils and/or atmosphere, especially with the aim of combatting climate change. Geoengineering can refer to a wide range of schemes, including: blasting sulfate particles into the stratosphere to reflect the sun's rays; 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 foliage can better reflect sunlight.

University of Calgary physicist and geoengineering advocate, David Keith, describes geoengineering as "an expedient solution that uses additional technology to counteract unwanted effects without eliminating their root cause.[1] In other words, geoengineering uses new technologies to try to rectify the problems created by the use of old technologies, a classic techno-fix.

Amidst growing public unease and increasing concentrations of carbon dioxide in the atmosphere, Organisation for Economic Co-operation and Development (OECD) countries are feeling the pressure to "bite the bullet" They either adopt socially-responsible policies to dramatically cut fossil fuel use and consumption, or, they can hope for an alternative – a "silver bullet" in the form of an array of techno-fixes that will allow them to maintain the status quo and dodge the consequences. No surprise, the silver bullet option – most clearly embodied in the form of geoengineering – is gaining momentum. Also not surprising: the states in the global North, which are responsible for almost all historic greenhouse gas (GHG) emissions and have either denied climate change or prevaricated for decades, are the ones warming most quickly to the geoengineering option. And they will 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 thermostat. Equally unsurprising is that 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 same folks who geoengineered us into this mess in the first place.

Choosing geoengineering flies in the face of precaution. Even 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, or even to risk real-world geoengineering experiments. We do not know if geoengineering is going to be inexpensive, as proponents insist – especially if / when geoengineering doesn't work, 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 around the world (sometimes referred to euphemestically as "spatial heterogeneity").[2] As much as the Industrial Revolution's unintended "geoengineering" experiment has disproportionately harmed people living in tropical and subtropical areas of the world, purposeful geoengineering experiments are liable to do the same.

The governments that are quietly contemplating funding geoengineering experimentation are the ones that have failed to pony up even minimal funds for mitigation or adaptation action on climate change. Indeed in some

1. In a book to be published December 2009 by Island Press, Climate Change Science and Policy, Steven Schneider, Mike Mastrandrea, Armin Rosencranz, editors. The quotation is available in an article online: www.ucalgary.ca/~keith/papers/89.Keith.EngineeringThePlanet.p.pdf (accessed 14 October 2009).
2. UK Royal Society, Geoengineering the climate: science, governance and uncertainty, 1 September 2009, p. 62; available on the Internet: http://royalsociety.org/document.asp?tip=0&id=8729

quarters the MAG approach (Mitigation, Adaptation and Geoengineering) are already being proposed for discussions on climate change.[3] These governments will eagerly divert climate change funding away from climate change mitigation and adaptation toward geoengineering if given the opportunity. After all, they can spend the money on their own scientists and corporations to launch initiatives that are more likely benefit their part of the world. There is no 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 more than 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 techniques deployed to address it – geoengineering is an act of geopiracy.

Box 1: What is Geoengineering?

Geoengineering is the intentional, large-scale intervention in the Earth's oceans, soils and/or the atmosphere with the aim of combatting climate change. Geoengineering includes a wide range of schemes, including: blasting sulfate particles into the stratosphere to reflect the sun's rays; dumping iron particles in the oceans to nurture CO_2-absorbing plankton; firing silver iodide into clouds to produce rain; genetically engineering crops to have reflective leaves. University of Calgary physicist, David Keith, describes geoengineering as "an expedient solution that uses additional technology to counteract unwanted effects without eliminating their root cause."[4]

3. See Institute of Mechanical Engineers, Climate Change: Have We Lost the Battle, November 2009, available at http://www.imeche.org/about/keythemes/environment/Climate+Change/MAG
4. Op. cit.

Part I: The Context

Technology, the UNFCCC and Geoengineering

The United Nations Framework Convention on Climate Change (UNFCCC) Conference (COP 15) in Copenhagen (7-18 December 2009) has been billed as the last chance for international negotiators to agree on a post-2012 Framework that can bring about significant reductions in GHG emissions. The first commitment period of the Kyoto Protocol, which entered into force in 2005 and set binding emission-reduction targets for 37 industrialized countries plus the European Community, expires in 2012.[5] A new legally binding climate agreement was supposed to be sealed in the Danish capital at COP 15, but the chances of this happening are now miniscule.

In fact, rich countries – Annex 1, in UNFCCC parlance – are busy in their own capitals downplaying expectations for the Copenhagen conference. Social movements and developing countries are determined to make sure that those who caused climate chaos take responsibility for it. The word in the hallways in Bangkok, during recent pre-COP 15 negotiations (28 September – 9 October), is that Annex 1 countries want to abandon the Kyoto Protocol and its notion of "common but differentiated responsibilities," which puts the onus on those who have historically been the biggest carbon-emitting countries, and hope to strong-arm developing countries into accepting a deal that makes everyone share the climate debt that wealthy countries have incurred. (It's difficult not to draw a parallel with the financial bailout where governments spent trillions of public dollars to protect banks and businesses while allowing more than a billion people to go hungry, including an additional 150 million people during the current food crisis – sparked itself, in part, by climate change and agrofuels that are supposed to mitigate climate change.[6])

The so-called Bali Action Plan (BAP), negotiated at the UNFCCC's COP 13 in 2007 established the Ad Hoc Working Group on Long-term Cooperative Action (AWG-LCA) to "enable the full, effective and sustained implementation of the Convention"[7] – in other words, to get things done. Technology has been designated as one of four "pillars" of the Action Plan. (The three other pillars are mitigation, adaptation and finance.) While there are few areas in which all Parties to the Convention agree, the best shot at consensus would likely start with a profession of faith in the power of technology to deliver solutions to climate chaos.

The UNFCCC's "Fact Sheet," Why is Technology so Important?, sums up the Convention's stance: "Environmentally sound technologies are able to provide win-win solutions, allowing global economic growth and climate change mitigation to proceed hand in hand."[8] In other words, technology will allow us to continue on our current trajectory without any reductions in production and consumption – in fact, technology will enable us to produce and consume more – without suffering consequences. Implicit in the faith of 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," according to the Fact Sheet.

Rich, panicky governments are hoping for quickfixes rather than risk inconveniencing their electorate or offending industry. As dangerous as geoengineering may sound (and turn out to be), governments around the world are aware that some action must be taken quickly. They're also aware that carbon-trading schemes won't put a dent in climate change. Geoengineering warrants serious debate and preemptive action.

5. The reduction targets amount to an average of five per cent against 1990 levels over the five-year period 2008-2012. See http://unfccc.int/kyoto_protocol/items/2830.php
6. The World Bank estimates that 75% of the 140% rise in world food prices between 2002 and 2008 was due to agrofuel production. See Asbjorn Eide, "The Right to Food and the Impact of Liquid Agrofuels (Biofuels)," FAO, Rome, 2008, available at http://www.fao.org/righttofood/publi08/Right_to_Food_and_Biofuels.pdf and Olivier de Schutter, Background Note: Analysis of the World Food Crisis by the UN Special Rapporteur on the Right to Food, available at http://www.srfood.org/images/stories/pdf/otherdocuments/1-srrtfnoteglobalfoodcrisis-2-5-08.pdf
7. See http://unfccc.int/meetings/items/4381.php
8. http://unfccc.int/files/press/backgrounders/application/pdf/fact_sheet_on_technology.pdf

References to technology are sprinkled throughout the ~200 pages of the negotiating text on Long-term Cooperative Actions,[9] with the section on Technology presenting diverse proposals for enhancing implementation of the Framework Convention. The terms "environmentally-sound technologies" (EST) and "innovative technologies" are ubiquitous though there is no explicit definition of what these concepts mean in the context of climate change mitigation and adaptation, and no specificity about which technologies are involved.

There are also numerous references to "enabling environment" 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. (See Geoengineering and Intellectual Property Claims, below.) The role of the private sector in the different stages of the "technology cycle" and in financing technology development is another very contentious issue. Parties have submitted proposals to leverage private investments in the deployment, diffusion and transfer of technologies, and in connecting private companies that can provide specific technologies to countries that have already adopted "appropriate measures" that may become pre-requisites for technology support. Some developed countries, for example, are proposing the promotion of voluntary technology agreements and partnerships in cooperative research and development and large-scale demonstration projects and technology deployment projects.

In all cases, the "technology cycle" is understood as: research, development, deployment, diffusion and transfer. There is no provision for assessment, and no institution charged with evaluating the impacts on climate or people. And there is no attempt to assess which technologies will be most immediately useful, and for whom. In fact, some ideas like the protection of traditional knowledge of small-scale farmers through seed-saving and crop rotations, which are known to cause no harm to the climate, play second fiddle to approaches such as industrial, high-input technologies like monoculture tree plantations for the production of agrofuels (still considered an environmentally sustainable technology) and biochar, i.e., using buried plant biomass as a carbon sink. It is essential for negotiators at the UNFCCC to keep in mind the full suite of technologies that may come into play, including geoengineering technologies.

While the word geoengineering does not (yet) appear in the negotiating text, as long as geoengineering techniques are not explicitly excluded, it could be assumed they are encompassed under the general term technology, and all the provisions on "enhanced action" could therefore apply. Geoengineering techniques that "manage solar radiation" (i.e., prevent sunlight from hitting the Earth) could also be implied in the temperature reduction targets adopted by states. Already, some geoengineering advocates (notably on ocean fertilization and biochar) have tried to use the Convention to get unproven technologies accredited under the Clean Development Mechanism (CDM), which allows countries with emission-reduction commitments to "move" their obligation to an emission-reduction project in a developing country. If a technology as potentially harmful as ocean fertilization or biochar becomes accredited under the CDM, the profits to be made by using the oceans and Earth as "carbon sinks" will quickly subordinate the other vital functions they serve – notably, but certainly not uniquely, as food sources.

The final section of this report, Reflections and Recommendations, includes desired outcomes for the current UNFCCC negotiations as well as tracing a path forward beyond Copenhagen.

9. Ad hoc Working Group on Long-term Cooperative Actions, FCCC/AWGLCA/2009/INF.2 15 September 2009, available at http://unfccc.int/resource/docs/2009/awglca7/eng/inf02.pdf

Box 2: The Squeaky Clean Development Mechanism

The Kyoto Protocol has three "market-based mechanisms" (emissions trading, joint implementation and the Clean Development Mechanism [CDM]), which were introduced in the last hours of the Kyoto negotiations. The CDM mechanism provides flexibility to rich countries unlikely to meet their emission reduction targets domestically by allowing them to buy "offsets" that support "clean" development in the South that would not have occurred without offsets (this is known as "additionality"). That means, theoretically, large polluters in the North will invest in sustainable projects in developing countries in order to compensate for the negative impact their own high emissions. The process is overseen by a CDM executive board, under the authority of the Conference of the Parties of the UNFCCC. The number of CDM projects has exploded recently, growing ten fold, for example, between 2005 and 2007 (from 10 to 100 proposals a month). More than 4000 total projects have been supported.

The CDM has been widely criticized at a conceptual level as well as for the way it operates on the ground. Indeed, the CDM itself acknowledges "the renewed urgency in 2009 [of] the task of improving the CDM."[10] One big problem is that it does not actually reduce emissions but rather buys the biggest polluters more time, worsening the climate crisis and allowing more and more GHGs into the atmosphere. In terms of its operations on the ground, common criticisms include: a very small number of countries have received the bulk of the projects;[11] local communities are not properly involved in decision making, resulting in social and environmental hardships; monoculture plantations by agro-forestry companies have replaced traditional and more sustainable land uses; large hydroelectric power stations with negative local impacts have also been certified under the CDM; indigenous peoples have not been able to properly assert their rights in the processes.

While the problems with carbon trading and offsetting are becoming steadily more apparent, influential states within the UNFCCC are working to increase the scope of such mechanisms, notably by the adoption and expansion of REDD (Reducing Emissions from Deforestation and Degradation in developing countries). Annex 1 countries are fighting for an ambitious role for the international financial institutions, particularly the World Bank, whereas developing countries are dis-satisfied with its undemocratic governance structure (based on financial contributions) and prescriptive economic policies that have been so harmful over the past two decades.

CDM is at the centre of current negotiations – both in regards to reform and expansion into "sectoral" mechanisms and "policy CDM," as well as the efforts to expand its scope to include technologies such as CCS, nuclear power and biochar. Critical assessment of CDM needs to include an understanding of what existing and new technologies are under consideration.

9. Ad hoc Working Group on Long-term Cooperative Actions, FCCC/AWGLCA/2009/INF.2 15 September 2009, available at http://unfccc.int/resource/docs/2009/awglca7/eng/inf02.pdf
10. UNFCCC, Clean Development Mechanism: 2008 in Brief, p. 3, available at http://unfccc.int/resource/docs/publications/08_cdm_in_brief.pdf
11. In 2008 for example, three quarters of the projects went to China, India, Brazil and Mexico. Fewer than 3% of projects have gone to Africa. See UNFCCC, Clean Development Mechanism: 2008 in Brief available at http://unfccc.int/resource/docs/publications/08_cdm_in_brief.pdf

How We Got Here: The Mainstreaming of Geoengineering

In a sense, geoengineering has always been on the table as a possible response to climate change. As early as 1965, the U.S. President's Science Advisory Committee warned, in a report called *Restoring the Quality of Our Environment*, that CO2 emissions were modifying the Earth's heat balance.[12] 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" and 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 usig clouds to counteract warming. As James Fleming, the leading historian of weather modification, wryly notes: The first ever official report on ways to address climate change "failed to mention the most obvious option: reducing fossil fuel use."[13]

Forty years after the release of the Science Advisory Committee's report, everybody, including – finally – the sitting U.S. 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 U.S. Congress agreed to study a bill that would establish a national "Weather Modification Operations and Research Board." (While the bill didn't pass, it was resucitated this year, made-over as the "Weather Mitigation Research and Development Policy Authorization Act." In late July, the Committee on Commerce, Science, and Transportation recommended the new bill be heard by the entire Senate.)

The current debate over the possibility of engineering the Earth's climate can be traced to a paper[14] co-authored by the late Dr. Edward Teller – the Nobel laureate responsible for the hydrogen bomb and one of the most politically influential U.S. scientists in the latter half of the 20th century. Teller lent his support to geoengineering when he and two colleagues submitted their paper to the 22nd International Seminar on Planetary Emergencies in Erice, Sicily in 1997. While the authors did not present their views as being endorsed by the U.S. government, their work was conducted at the Lawrence Livermore National Laboratory, under contract with the U.S. Department of Energy.

Teller might have been dismissed as a scientist past his prime (he was 89 years old at the time of the Sicilian seminar, after all) except that another Nobel laureate, Paul J. Crutzen – who won his Prize for pioneering work on the ozone layer – amplified the scientific shockwave in 2002 when he offered grudging support for geoengineering in the journal *Nature*.[15] Since we're living in the "anthropocene" era when humans are increasingly affecting the climate, Crutzen suggested, our future "may well involve internationally accepted, large-scale geoengineering projects." The same year, *Science* published its own article arguing for geoengineering as a legitimate approach to combat climate change.[16]

Also in 2002, Teller, who worked for the U.S. Department of Energy, along with colleagues Roderick Hyde and Lowell Wood, submitted an article to the U.S. National Academy of Engineering in which they argued that geoengineering – not reduction of GHG emissions – "is the path mandated by the pertinent provisions of the UN Framework Convention on Climate Change."[17]

In 2005, another high profile climatologist, Yuri Izrael, former vice-chair of the Intergovernmental Panel on Climate Change 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 sulfur aerosol into the atmosphere to take a few degrees off global temperatures. Izrael has since claimed to be preparing small-scale geoengineering experiments.

Paul Crutzen returned to the debate in August 2006 when he wrote an "editorial essay" in the journal *Climatic*

12. James Fleming, "The Climate Engineers," Wilson Quarterly, spring 2007, available online: http://www.wilsoncenter.org/index.cfm?fuseaction=wq.essay&essay_id=231274 10. UNFCCC, Clean Development Mechanism: 2008 in Brief, p. 3, available at http://unfccc.int/resource/docs/publications/08_cdm_in_brief.pdf
13. Ibid. The rest of this section relies heavily on Fleming's article.
14. Edward Teller, Lowell Wood and Roderick Hyde, "Global Warming and Ice Ages: I. Prospects For Physics-Based Modulation Of Global Change," 15 August 1997.
15. P.J. Crutzen, "Geology of Mankind," Nature, Vol. 415, 3 January 2002.
16. M.I. Hoffert, K. Caldeira, et al. "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet," Science, Vol. 298, 1 November 2002, pp. 981-987 and P.J. Crutzen, "Geology of Mankind," Nature, Vol. 415, 3 January 2002.
17. E. Teller, R. Hyde and L. Wood, "Active Climate Stabilization: Practical Physics-Based Approaches to Prevention of Climate Change," 18 April 2002.

Change calling for active research into the use of "sub-micrometer" -sized sulfate-based aerosols to reflect sunlight into the stratosphere in order to cool the Earth.[18] Crutzen, a professor at the Max-Planck-Institute for Chemistry in Mainz, Germany, opined that high-altitude balloons and artillery cannons could be used to blast sulfur dioxide into the stratosphere, in effect, simulating a volcanic eruption. The sulfur dioxide would convert to sulfate particles. The cost, he reckoned, would run between $25 and $50 billion per year – a figure, he argued, that was well below the trillion dollars spent annually by the world's governments on defense. 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 fails. 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 U.S. National Academy of Sciences, also supported further research on Crutzen's geoengineering proposals. He told The *New York Times* in mid-2006: "We should treat these ideas like any other research and get into the mind-set of taking them seriously."[19]

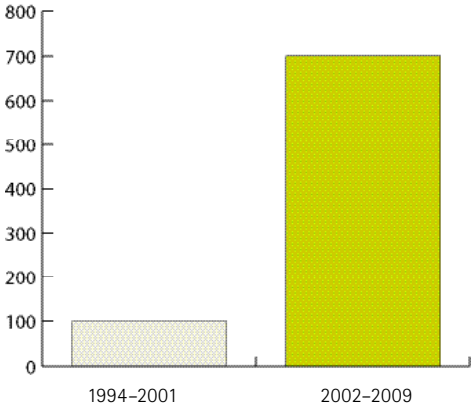
By November, NASA's Ames Research Center had convened an elite meeting of geoengineering advocates to explore options with Lowell Wood presiding. "Mitigation is not happening and is not going to happen," the aging physicist reportedly told the group. The time has come, he argued, for "an intelligent elimination of undesired heat from the biosphere by technical ways and means." According to Wood, his engineering approach would provide "instant climatic gratification." From that meeting came the beginnings of a campaign to secure funding for geoengineering techniques – requiring the field to gain respectability – and fast.

18. P.J. Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" Climatic Change, 2006.
19. William J. Broad, "How to Cool a Planet (Maybe)," The New York Times, June 27, 2006.

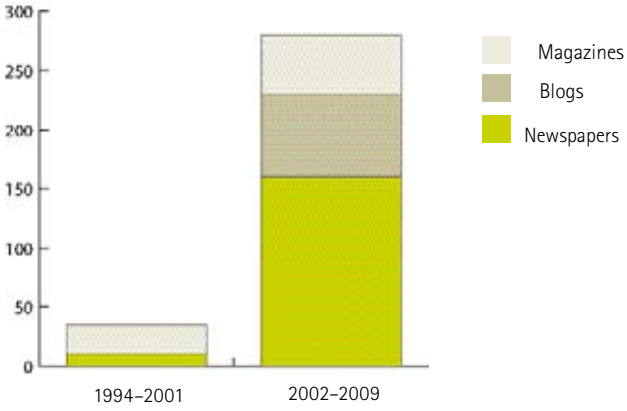
Media Blitz: Increase in Publications While Policymakers Test the Waters

To date current support for geoengineering has come from scientific and political circles, as well as mainstream media. Once a few prominent climate scientists had endorsed geoengineering as a scientifically credible endeavor – in print – publishing in the field exploded both in scholarly journals (almost a five-fold increase) and in the popular press (a 12-fold increase), as seen in the graphs below.[20] It is now politically-correct to talk about geoengineering as a legitimate response to climate change: a credibility shift that The New York Times called a "major reversal." [21]

Scientific Articles on Geoengineering before and after 2002



Media Coverage of Geoengineering Articles before and after 2002



In April 2009, John Holdren, Chief Science Advisor to U.S. President Barack Obama, conceded that the administration is considering geoengineering options to combat climate change.[22] The next month, U.S. Energy Secretary Steven Chu indicated his support for technological solutions to climate change, including "benign" geoengineering schemes that whitened rooftops.[23] In June, the National Academies – the body tasked with advising the U.S. government on scientific issues – hosted a two-day workshop on "Geoengineering Options to Respond to Climate Change: Steps to Establish a Research Agenda."[24] Steven Koonin, Under Secretary for Science in the U.S. Department of Energy, was instrumental in preparing a report published in July, which considered the technical feasibility of putting aerosol sulfates in the stratosphere to lower global temperatures.[25]

On the other side of the Atlantic, the science policy establishment was also warming to geoengineering. A high-profile exhibition at London's Science Museum, "Can Algae Save The World?" coincided with reports that a senior UK environment minister was a closet fan of ocean fertilization. In a 2008 letter submitted to a geoengineering blog, the anonymous minister wrote that "ocean fertilization, because of it's [sic] enormous potential simply must (I will emphasize the word must) be explored vigorously…the question is how to do this without engendering public opposition."[26]

20. Publication searches were conducted August 25, 2009. For scholarly articles: Google Scholar for the years 1994-2001 and 2002-present (search terms "geoengineering" and "climate" "change" in the following categories: Biology, Life Sciences, and Environmental Science; Chemistry and Materials Science; Engineering, Computer Science, and Mathematics; Physics, Astronomy, and Planetary Science; Social Sciences, Arts, and Humanities. For major media coverage: Lexis Nexis for the years 1994-2001 and 2002-present (search terms "geoengineering" "climate" "change") in newspapers stories (major world newspapers), weblogs and magazines.

21. William J. Broad, "How to Cool a Planet (Maybe)," The New York Times, June 27, 2006.

22. Seth Borenstein, Associated Press, April 9, 2009. See "Global warming is so dire, the Obama administration is discussing radical technologies to cool Earth's air," available online: http://abcnews.go.com/Technology/GlobalWarming/wireStory?id=7295178

23. Steven Chu discussed geoengineering at the St James's Palace Nobel Laureate Symposium in London held on May 26-28, 2009.

24. See www.americasclimatechoices.org/GeoEng%20Agenda%206-11-09.pdf

25. J. J. Blackstock, 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, Climate Engineering Responses to Climate Emergencies (Novim, 2009), archived online at: http://arxiv.org/pdf/0907.5140

26. Accessed 16 October 2009 at http://carbonsequestration.blogspot.com/2008/02/uk-environmental-minister-ocean.html

The UK Parliamentary Innovation, Science, University and Skills Committee has issued a report recommending research into geoengineering based on input from its 2008-2009 session.[27] Early in 2009, the German Minister of Research authorized an ocean fertilization geoengineering experiment in the Scotia Sea despite the existence of a moratorium on the practice that his own government had helped broker at the UN Convention on Biological Diversity in 2008.[28]

In April 2009, Portugal's Ministry for Science, Technology and Higher Education convened a Chatham House Rules session on geoengineering.[29] In September, the Royal Society – the UK's national academy of science – followed with the launch of a report, Geoengineering the Climate: Science, Governance and Uncertainty,[30] giving geoengineering arguably its biggest credibility-boost to date.

The authors of the Royal Society report argued that geoengineering is "an insurance policy" – an unsatisfactory and hopefully distant Plan B, but one that should be considered if we find ourselves in a climate "emergency." The authors acknowledge that there are many ways to geoengineer the planet and admit that little is known about the potential social and environmental impacts. The report recommends that governments fund a dedicated, ten-year internationally coordinated geoengineering research programme (£100 million of which would come from the UK government). The bulk of this research would be in the form of monitoring and computer simulations, but the report also recommends field trials for several technologies.

From some perspectives, the report's insistence that geoengineering be understood as "an insurance policy" may seem prudent, practical and even precautionary. But the report's explicit endorsement of geoengineering research and real-life experimentation – and its unwillingness to reject even the most outlandish schemes[31] – is troubling. The impetus for the report, according to the Royal Society, was the need to equip governments and society with an analysis of the scientific risks and benefits involved. Officials have pointed to the escalating interest in geoengineering over the previous several months and insisted that they felt obliged to take on the task of bringing "rigour" to an increasingly polemical debate.[32]

Unfortunately (or maybe predictably) the occasion of the Royal Society report was used by several advocates of the geoengineering approach as an apt moment to amplify their own viewpoints. Neoconservatives across the Atlantic cooperated to launch a high profile report on why geoengineering is cheaper than climate mitigation (see "The Lomborg manoeuvre" below), the UK's Institute of Mechanical Engineers pipped the Royal Society to the post by releasing their own favourable analysis of geoengineering one day earlier and one of the Royal Society's own working group members, Dr Peter Cox (who is developing a geoengineering project that targets West Africa) used the release of the report to launch a special geoengineering edition of *Physics World* under the mantra "Time to lift the geoengineering taboo"[33]. The result was that the details of the Royal Society's report were lost under an avalanche of simultaneous pro-geoengineering press releases.

Geoengineering has also recently received attention from international agencies such as the World Bank – in its latest *World Development Report*[34] – and the United Nations Environment Programme (UNEP) in its recent compendium of scientific knowledge published since the last IPCC report.[35] The UNEP suggests that the issue of liability vis-à-vis geoengineering must be discussed but is pessimistic on

27. See Recommendations 24 and 25 of House of Commons Innovation, Universities, Science and Skills Committee, Engineering: turning ideas into reality, Fourth Report of Session 2008–09, Volume 1, p. 117.
28. For more information, see ETC Group news release, "German Geo-engineers Show Iron Will to Defy Global UN Moratorium," 8 Jan. 2009, available online at http://www.etcgroup.org/en/materials/publications.html?pub_id=710
29. See http://www.irgc.org/Geoengineering.html
30. Available online at www.royalsociety.org/displaypagedoc.asp?id=35151
31. Even geoengineering schemes such as covering deserts in reflective polyethylene-aluminum or putting mirrors in space, for example, are not dismissed from future consideration and therefore could be eligible for research funding from the UK government.
32. Personal email communication between Royal Society Director of Science Policy and ETC Group.
33. (http://www.iop.org/Media/Press%20Releases/press_36613.html).

the prospects for any international governance or regulation: "Considering how difficult it has been to reach agreement on the obvious climate challenge solutions based on common but differentiated responsibilities, the uncertainties involved in geoengineering schemes will likely prohibit any global agreement on deliberately interfering with Earth's Systems."[36] Previous reports of the IPCC have made only cursory and critical mentions of geoengineering, but its next report is likely to cover the field in more depth, given geoeengineering's recent credibility surge and that a number of prominent geoengineering scientists sit on its panels.

"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.[37]"
Sir Richard Branson, industrialist and airline owner

34. "Geoengineering the world out of climate change" in World Development Report 2010: Development and Climate Change, Box 7.1, p. 301; online at http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTWDRS/EXTWDR2010/0,,menuPK:5287748~pagePK:64167702~piPK:64167676~theSitePK:5287741,00.html
35. UNEP, Climate Change Science Compendium 2009, online at http://www.unep.org/compendium2009/
36. Ibid., p. 53.
37. Andew C. Revkin, "Branson on the Power of Biofuels and Elders," Dot Earth Blog, The New York Times, October 15, 2009, online at http://dotEarth.blogs.nytimes.com/

The Lomborg Manoeuvre: Once Climate Change Denier, Now Geoengineering Devotee

An odd effect of geoengineering's mainstreaming has been an alignment of the positions of some interest groups 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 fearing devastating effects from climate change, a new and powerful corporate lobby for geoengineering has emerged in the last two years made up of people whose motivation has never been concern for the environment or the world's poorest people.

In June 2008, Newt Gingrich, former Speaker of the House in the U.S. 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 sulfates 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. "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."[38]

Gingrich is a senior fellow of the American Enterprise Institute (AEI) – a neo-conservative think tank promoting free enterprise and limited government – closely associated with the recent Bush administration. AEI has its own full-time geoengineering project led by Lee Lane, a climate advisor to the Bush administration. In 2009, Lane published An Analysis of Climate Engineering as a Response to Climate Change,[39] a report advocating geoengineering as the economically preferable option over emissions reduction. Lane and his co-author claimed that emissions reductions strategies such as carbon taxes would diminish global GDP by 12.9% by 2100 (other estimates say 3%) whereas spraying seawater into clouds would both fix climate change and add 20 trillion dollars to the global economy. The report was published and widely broadcast by Bjørn Lomborg's Copenhagen Consensus Center. Lomborg is best known as the self-styled and controversial "Skeptical Environmentalist" who has consistently downplayed the existence and importance of climate change much to the anger of climate scientists. Lomborg is now using his "Copenhagen Consensus Center" to push for geoengineering not as a "Plan B" on climate change, but a "Plan A" – the preferred route to cooling the planet.

The "Lomborg manoeuver" – switching from opposing real-world action on climate change to supporting the most extreme possible action on climate change – is now becoming seemingly de rigueur among former climate change skeptics and "deniers," especially in the United States. Besides Lane and Gingrich at AEI, political operators at The Cato Institute, the Thomas Jefferson Institute, the Hoover Institution, the Competitive Enterprise Institute, the Hudson Institute, the Heartland Institute, the International Policy Network and elsewhere are now increasingly professing their faith in the geoengineering gospel. While climate scientists and activists have just begun to debate geoengineering, the topic 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" – with several invited talks and presentations by geoengineering advocates.

For those who previously doubted (or still do) the science of anthropogenic global warming, the geoengineering approach shifts the discussion from reducing emissions to an end-of-pipe solution. Once geoengineering is an option, there is no longer a need to bicker about who put the carbon dioxide in the atmosphere (or ask them to stop). If we have the means to suck up greenhouse gases or turn down the thermostat, emitters can continue unabated. At least one commentator has charged that the wholesale embrace of geoengineering by industry-friendly think tanks represents a deliberate tactic of distraction and delay by the same folks who formerly used oil company dollars to discredit the science of climate change. "If we can be made to believe that mega-scale geoengineering can stop climate change, then delay begins to look not like the dangerous folly it actually is, but a sensible prudence," explains Alex Steffen, editor of Worldchanging.com.[40] Indeed, at least one high profile climate skeptic, Julian Morris of the International Policy Network, asserts, "Diverting money into controlling carbon emissions and away from geoengineering is probably morally irresponsible." [41]

38. http://newt.org/tabid/102/articleType/ArticleView/articleId/3475/Default.aspx
39. Available online at http://fixtheclimate.com/component-1/the-solutions-new-research/climate-engineering
40. Alex Steffen, "Geoengineering and the New Climate Denialism," 29 April 2009; available on the Internet at http://www.worldchanging.com/archives/009784.html
41. Chris Bowlby, "A quick fix for global warming," BBC News, 31 July 2008; available on the Internet at http://news.bbc.co.uk/2/hi/uk_news/magazine/7533600.stm

Technology, the UNFCCC and Agriculture

While the focus on this report is on the emerging geoengineering technologies, one must not forget the many other existing technology areas that pose similar challenges. Apart from obvious, controversial technologies such as nuclear power and carbon capture and storage (CCS), technologies related to agriculture and land use are key in the context of climate change negotiations.

According to the IPCC, agriculture is the source for 14% of global GHG emissions, with the bulk coming from industrial production due to the heavy reliance on fossil fuels throughout its supply chain. Small-scale agriculture, in addition to feeding the majority of the world's people,[42] has a much lighter footprint. Nonetheless, the UNFCCC negotiations have largely ignored the fate of peasant agriculture and are focusing on how to increase the "productivity" of large-scale, industrial agriculture and to "enhance" its value by exploiting its potential as a carbon sink, especially via fast-growing monocultures and biochar, with REDD (Reducing Emissions from Deforestation and Degradation in Developing Countries) as the dominant model for discussion.

While commercial breeders (of crops and livestock) stress yield and uniformity (both for patenting and processing) and depend heavily on external inputs, peasant breeding stresses reliability and resistance to pests, diseases and adverse weather conditions. As global agriculture encounters climate change, farmers will not only face radically different temperatures and growing conditions, but also highly erratic conditions that will place the premium on diversity and flexibility. In other words, large monocultures of genetically uniform plant varieties will be the most vulnerable to climate change. This does not mean that peasants have found the answer to climate change and we can all relax. Nothing can lessen the grim reality that agriculture in the global South is experiencing the first and most damaging impacts of climate change already.

But it does mean that peasants must take the lead in developing strategies – including technological strategies – to meet the food and climate crises. This doesn't mean abandoning the potential for conventional laboratory research. The Western model of science and technology has developed micro-techniques that can have macro applications – high-tech advances that have applications throughout all of – or much of – the world. Peasant research often develops macro-technologies for microenvironments – "wide-tech" complex, integrated strategies that are location specific.

Agbiotech, biofuels and synthetic biology firms are all racing to develop "climate-ready crops" that will sequester carbon dioxide, reflect solar rays, or withstand environmental stresses attributable to climate change (extreme heat, drought, for example). Grown over large areas of plains, prairies, pampas or the Punjab, the theory is that agricultural crops with one or more of these traits could play a useful role in protecting the planet from climate change or adapting it to a warming world while continuing to provide food, feed, fuel and fiber.

A recent report by the ETC Group[43] identified 532 recent patent applications for crops engineered with climate-ready traits. Six of the world's largest chemical companies (BASF, Monsanto, Bayer, DuPont, Dow and Syngenta) are actively engaged in developing climate-ready crops. BASF and Monsanto have a $1.5 billion joint venture developing climate-ready varieties and, together, have control of half of the 55 core patents identified by ETC Group in May 2008. Indirectly (with their smaller biotech partners), the two companies control almost two-thirds of the key climate-ready patents.

The implications of industrially produced, genetically engineered climate-ready crops with a small number of powerful multinational companies controlling most of the food chain are serious for both climate change and food security. Certainly, if vast areas of cropland are sown to genetically uniform plant varieties – especially in tropical and subtropical areas of intense sunlight – the strategy could exacerbate genetic erosion and species displacement. Most significantly, moving crop production onto lands formerly free of industrial agricultural production (such as wetlands)

42. ETC Group, "Who Will Feed Us? Questions for Food/Climate Crises Negotiators in Rome and Copenhagen," Communiqué #102, November, 2009, www.etcgroup.org.
43. ETC Group, "Patenting the 'Climate Genes'...And Capturing the Climate Agenda," Communiqué #99, May/June 2008, on the Internet: http://www.etcgroup.org/en/materials/publications.html?pub_id=687

could threaten the biodiversity of those ecosystems and the livelihoods of people who live there. If climate-ready traits outcross to wild varieties or via horizontal gene flow in the soil, significant ecosystem changes could follow. If the modified varieties require special chemical applications, the increase in chemical-use could be detrimental to local flora, fauna, farmers and consumers.

The Copenhagen process will likely deliver a programme of work on agriculture to the UNFCCC's SBSTTA (Subsidiary Body for Scientific and Technological Advice). If we are not to exacerbate the problems that biotechnology has already delivered to the world's food systems, representatives of small-scale farmers and real sustainable agriculture will need to find their way to the negotiating table.

Part II:

Geoengineering: The Technologies

Geoengineering technologies can be divided into three broad areas: solar radiation management (SRM), carbon dioxide removal and sequestration, and weather modification. In this section we first provide a condensed overview of the key technologies currently under development, followed by three case studies with more in depth analysis and a concluding section on the link to intellectual property rights.

Box 3: Proof of Principle – Is Geoengineering Feasible?

Unfortunately, humanity has already proven massive Earth restructuring to be wonderfully operational. Fill enough wetlands and introduce crop monocultures in enough fields and the ecosystem changes. Cut down enough forests and the climate changes. Build up sufficient industrial pollution and the ozone disappears and the smog rolls in. Geoengineering's "proof of principle" is manifest!

Ten old ways to geoengineer the planet:

- Cut down most of the world's forests;
- Convert savannas and marginal land into monoculture cropland;
- Dam watersheds, divert rivers, dry-up wetlands and drain aquifers;
- Pump billions of tonnes of industrial pollutants, car exhaust and other toxic chemicals into the stratosphere and soil every year;
- Wipe out species and genetic diversity in livestock & crops;
- Overuse marginal lands leading to soil erosion and desertification;
- Erode the world's major ecosystems;
- Deplete – possibly beyond recall – most commercial marine species;
- Condemn half of the world's coral reefs to extinction;
- Pollute almost all of the world's fresh water reserve.

Ten new ways to geoengineer the planet:

- Create vast monoculture tree plantations for biochar, biofuels & CO_2 sequestration;
- Contaminate Centres of Genetic Diversity with DNA from genetically engineered crops;
- "Fertilize" the ocean with iron nanoparticles to increase phytoplankton that theoretically sequester CO_2;
- Proliferate nuclear power plants;
- Build 16 trillion space sunshades to deflect sunlight 1.5 million km from Earth;
- Launch 5,000-30,000 ships with turbines to propel salt spray to whiten clouds to deflect sunlight;
- Drop limestone into the ocean to change its acidity so that it can soak up extra CO_2;
- Store compressed CO_2 in abandoned mines and active oil wells;
- Biannually, blast sulfate-based aerosols into the stratosphere to deflect sunlight;
- Cover deserts with white plastic to reflect sunlight.

Solar Radiation Management (SRM)

Solar radiation management technologies aim at countering the effects of the greenhouse gases by increasing the radiation of sunlight back into space. Some of these technologies intend to do this by altering conditions at the surface of the Earth by covering deserts with reflective plastic material; other technologies aim to modify the atmosphere by adding reflective 'pollution', while some technologies even try to block some of the incoming sunlight by installing shades in space. Common to all these technologies is that they do not influence the concentration of greenhouse gases; they are only intended to counter some of their effects. A removal or malfunctioning of these technologies would thus lead to drastic temperature increases very quickly.

Implications:
"Solar radiation management" (blocking or reflecting sunlight) has the potential to cause significant environmental damage, including releasing additional greenhouse gases into the atmosphere, changing weather patterns and reducing rainfall, damaging the ozone layer, diminishing biodiversity, making solar cells less effective by reducing the amount of received sunlight, and risking sudden climatic jumps if the efforts are stopped. SRM will not address the problem of atmospheric GHGs or ocean acidification. Even more critically: who controls the Earth's thermostat? Who will make the decision to deploy if such drastic measures are considered technically feasible?

Table 1: Geoengineering Technology

Geoengineering Technology	Description	Key Researchers/Advocates
Aerosolized sulfates in stratosphere	Pumping aerosolized sulfates into the stratosphere to block sunlight, thereby lowering the Earth's temperature. This has no effect on the level of GHGs in atmosphere.	Lowell Wood (Lawrence Livermore National Laboratory, USA), Ken Caldeira (Stanford University, USA), Yuri Izrael (Research Institute of Global Climate and Ecology, Russian Academy of Sciences, Moscow), Paul Crutzen (Max Planck Institute of Chemistry, Germany)
Space sunshades	Trillions of small, free-flying spacecrafts would be launched a million miles above the Earth to form a cylindrical "cloud" 60,000 miles long, aligned with the orbit of the sun, which should divert about 10% of sunlight away from the planet.	Roger Angel and Nick Woolf (University of Arizona, USA), David Miller (Massachusetts Institute of Technology, USA), S. Pete Worden (NASA, USA)
Cloud whitening	Spraying seawater into clouds to increase their condensation nuclei; the clouds will be "whiter" and will reflect more of the sunlight away from Earth.	John Latham (University of Manchester, UK), Stephen Salter (University of Edinburgh, UK)

Geoengineering Technology	Description	Key Researchers/Advocates
Desert covering	Covering large expanses of desert with reflective sheets to reflect sunlight away from Earth.	Alvia Gaskill (Environmental Reference Materials, Inc., USA)
Arctic ice covering	Covering snowpack or glaciers in the Arctic with insulating material or a nano-film to reflect sunlight and prevent melting.	Leslie Field (Stanford University and Ice911 Research Corporation, USA), Jason Box, Ohio State University, USA
White roofs and pavements	Painting roofs and road surfaces white to reflect sunlight (low-tech geoengineering).	Hashem Akbari and Surabi Menon (Lawrence Berkeley National Laboratory, USA)
"Climate ready" crops	Includes technologies to increase albedo (reflectivity) and to make plants and trees drought, heat or saline resistant.	Andy Ridgwell (University of Bristol, UK); all agbiotech firms, including BASF, Syngenta, Monsanto
Space mirrors	Putting a superfine reflective mesh of aluminum threads between Earth and sun.	Dr Lowell Wood and Professor Edward Teller (Lawrence Livermore Lab, USA), Stewart Brand, The Long Now Foundation, USA

Carbon Dioxide Removal and Sequestration

Carbon dioxide removal and sequestration are geoengineering technologies that attempt to remove carbon dioxide from the atmosphere after it has been released. Some of the technologies use mechanical devices to do so, others modify the chemical balance in the oceans to stimulate increased uptake of CO_2, while other technologies manipulate species and ecosystems to create new forms of carbon 'sinks'.

Most of these technologies intervene in complex ecosystems with the goal of modifying them and are therefore likely to cause unpredictable side effects. 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/ocean use changes, which will negatively affect poor and marginalized people.

Implications:

Geoengineering Technology	Description	Key Researchers/Advocates
Ocean fertilization 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.	Dan Whaley and Margaret Leinen (Climos, Inc., USA), Victor Smetacek (Alfred Wegener Institute, Germany); Wajih Naqvi (National Institute of Oceanography, India); Ian S.F. Jones (Ocean Nourishment Corporation, Australia), Russ George (Planktos Science, USA), Michael Markels (GreenSea Ventures, Inc., USA)
Carbon capture and sequestration (CCS)	Diverse technologies that use biological, chemical or physical processes to bury carbon in geological formations such as depleted petroleum reserves, coal beds or deep in the seabed (CO_2 lakes).	David Keith (University of Calgary, Canada), petroleum companies such as Royal Dutch Shell and BP
Biochar	Burning biomass through pyrolysis (in low oxygen environments so carbon is not released) and burying the concentrated carbon in soil.	Peter Read (Massey University, New Zealand), Johannes Lehmann (Cornell University, USA), Craig Sams (Carbon Gold, UK), Tim Langley (Carbonscape, NZ)
Carbon-sucking machines 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.	David Keith (University of Calgary, Canada), Klaus Lackner (Global Research Technology, LLC, USA), Roger Pielke (University of Colorado, USA and Oxford, UK)

Geoengineering Technology	Description	Key Researchers/Advocates
Ocean upwelling or downwelling enhancement	Using pipes to bring up nitrogen or phosphorous enriched seawater to the surface to cool surface waters and enhance ocean sequestration of CO_2.	James Lovelock (UK) and Chris Rapley (London Science Museum, UK), Philip W. Kithil, (Atmocean, Inc., USA)
Adding carbonate to the ocean	Increasing ocean alkalinity in order to increase carbon uptake.	Ian S.F. Jones (Ocean Nourishment Corporation, Australia), Tim Kruger (CQuestrate, UK)
"Enhanced Weathering"	Controlling levels of atmospheric CO_2 by spreading fine-powdered olivine (magnesium iron silicate) on farmland or forestland.	R. D. Schuiling and P. Krijgsman (Institute of Earth Sciences, Utrecht, Netherlands)
Large scale land-use change/ rainwater harvesting	Engineering large-scale changes in water movements in order to provoke cloud formation to reflect sunlight.	Peter Cox (University of Exeter, UK), Ray Taylor (The Global Cooling Project, UK)
"Crop Residue Ocean Permanent Sequestration"	Storing carbon by dumping tree logs into seawater.	Stuart Strand (University of Washington, USA)
Genetically engineered algae and marine microbes	Engineering communities of synthetic microbes and algae to sequester higher levels of carbon dioxide, either for altering ocean communities or for use in closed ponds Engineering communities of synthetic microbes and algae to sequester higher levels of carbon dioxide, either for altering ocean communities or for use in closed ponds.	J. Craig Venter (Synthetic Genomics, Inc., USA)

Weather Modification

The idea that humans might intentionally control the weather has a long history reaching back to indigenous rain dances and lighting of fires. Since the 1830's governments and private companies have attempted to apply technological know-how to produce precipitation or restrain storms by altering landforms, burning forests and dropping chemicals into clouds – both for military and agricultural purposes. As climate change ushers in increased extreme weather events ranging from drought to tropical storms, attempts to control weather are now witnessing a resurgence. Weather modification is a classic 'end of the pipe' geoengineering response that addresses neither the causes nor the mechanism of climate change itself but only seeks to alter its outcomes. Weather modification has also been advanced as an adapation technology for climate change (e.g., for protecting water flow for hydropower schemes).

Implications:
Given the uncertainty in predicting even natural weather, proving the efficacy of artificial weather is notoriously difficult, but the agronomic and geopolitical implications may be very significant. Since weather is complex and inherently transboundary there may be unwelcome and unpredictable side effects at weather modification attempts. Producing rainfall at one location may be regarded as a 'theft' of that rainfall from elsewhere, especially if crops fail as a result. Interventions such as switching the course of a hurricane may cause extensive damage at another site and may no longer be considered 'an act of God.' A series of attempts at weather warfare during the Vietnam war under the codename "Operation Popeye" led to an international agreement to ban hostile uses of weather modification techniques. The line between what is a hostile or peaceful use may be difficult to determine.

Cloud seeding	Dropping chemicals (usually silver iodide) into clouds to precipitate rain or snow - already practiced on a large scale in the U.S. and China, despite skepticism of effectiveness.	Chinese Meteorological Association; Bruce Boe (Weather Modification, Inc.)
Storm modification	Attempting to prevent formation.	Gel Technologies Inc

44. See, for example, plans by Pacific Gas and Electric Company (California) to use cloud seeding in the Pit and McCloud Watersheds to offset snow pack loss from climate change: Christina Aanestad, "Seeding Clouds for Hydropower," Climate Watch, KQED Radio, 2009, online at http://blogs.kqed.org/climatewatch/2009/09/05/seeding-clouds-for-hydropower/

Box 4: Geoengineering – A Brief Technical History

It has taken us some time to realize the influence we can wield over the planet. Back in 1930, Robert Millikan – physicist and Nobel Laureate – insisted there was no danger that human activity could do lasting harm to anything as massive as Earth. Even as he was speaking, chemists were inventing CFCs – chlorofluorocarbons – the chemical cocktail responsible for thinning stratospheric ozone at an alarming rate, whose use eventually led to intergovernmental policy action in the mid-1980s: The Vienna and Montréal Accords phased out the production of CFCs.

Likewise, the notion of a technological fix for global warming isn't new either. In the 1940s, Bernard Vonnegut (the novelist Kurt Vonnegut's brother) – a well-respected meteorologist – discovered that silver iodide smoke could cause clouds to give up their rain. His discovery kick-started serious government efforts to manipulate the environment. Until then, cloud-seeding had been the preserve of crackpots and con artists, but by 1951, 10 % of the U.S. was said to be under clouds that had been commercially seeded. Governments and industry have a sometimes ignoble history tampering with the weather, including the CIA's top secret "Project Popeye" rainmaking campaign that began in 1966 and ran for seven years, conducting 2300 cloud seeding missions over the Ho Chi Minh Trail during the Vietnam War. The goal was to make the Trail impassible and, as a bonus, to drown out North Vietnam's rice crop. (While rains did increase, the Air Force couldn't establish a clear link between this and the covert campaign.)

As the UN Conference on the Human Environment was convening in Stockholm in 1972, a cloudburst drowned 238 people in Rapid City, South Dakota, USA on a day when seeding experiments were going on nearby. Over time, the public has built up a healthy distrust of both public and private efforts to inject natural clouds with artificial silver linings.

Recently, more convincing experiments have focused on "hygroscopic cloud seeding" – that is, warm-cloud seeding as opposed to cold-cloud seeding (glaciogenic). Results from experiments at the South African National Precipitation and Rainfall Enhancement Programme earned researchers there the United Arab Emirates' 2005 Prize for Excellence in Advancing the Science and Practice of Weather Modification. Other warm-cloud seeding projects have taken place in the USA, Thailand, China, India, Australia, Israel, South Africa, Russia, United Arab Emirates and Mexico. According to the UN's World Meteorological Organization (WMO), at least 26 governments were routinely conducting weather-altering experiments at the turn of this century. By 2003-2004, only 16 World Meterological Organization member countries reported weather modification activities, although weather modification activities are known to have taken place in many other countries.

Many of the world's military powers remain fascinated with weather control. A U.S. Air Force report entitled **Weather as a Force Multiplier: Owning the Weather in 2025** concluded that the weather "can provide battlespace dominance to a degree never before imagined," including the ability to thwart an enemy's operations by enhancing a storm or by inducing drought and reducing fresh water supplies. In 2004, two Chinese cities in Henan province – Pingdingshan and Zhoukou – came close to fighting when both cities' leaders tried to alter local weather patterns by blasting tiny silver iodide particles into the troposphere (the lowest portion of Earth's atmosphere). The city downwind accused the city upwind of stealing its weather. This didn't deter the Chinese government from using weather modification to fend off rain during the 2008 Beijing Olympics. That effort was dwarfed by the weather intervention at the beginning of October 2009 – involving 260 technicians and 18 aircraft – which tried to secure clear skies for the National Day Parade.

Case Study 1: Ocean Fertilization

The theory

Oceans play a key role in regulating the world's climate. Phytoplankton (microorganisms that dwell on the surface of the ocean), despite their minute size, collectively account for half of the carbon dioxide absorbed annually from the Earth's atmosphere by plants. Through the process of photosynthesis, plankton capture carbon and sunlight for growth, releasing oxygen into the atmosphere. The world's oceans have already absorbed about a third of all carbon dioxide (CO_2) humans have generated over the last 200 years.[45] According to NASA, about 90% of the world's total carbon content has settled to the bottom of the ocean, mostly in the form of dead biomass.[46]

Proponents of ocean fertilization posit that dumping "nutrients" (generally iron, nitrogen or phosphorous) in waters identified as "high nutrient low chlorophyll" (HNLC) – i.e., 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 enterprises engaged in ocean fertilization 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. According to NASA satellite data, as water temperatures increased from 1999 to 2004, the ocean's microscopic plant life dropped significantly. Oceans around the equator in the Pacific saw as much as a 50 percent drop in phytoplankton production. Advocates of iron fertilization schemes believe that iron is the missing nutrient that will restore phytoplankton and sequester two to three 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 nutrient-rich but anemic – 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, U.S. and Canadian scientists, writing in the journal Science, point out that "the oceans' food webs and biogeochemical cycles would be altered in unintended ways."[47] They warn that if carbon trading schemes make it profitable for companies to engage in ocean fertilization, "the cumulative effects of many such implementations would result in large-scale consequences – a classic 'tragedy of the commons.'" 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 fertilization and at least 13 experiments have been carried out in the world's oceans over the past 20 years. A 2007 experiment near the Galapagos Islands by U.S. start-up Planktos, Inc. was stopped because of an international civil society campaign (see Box 5, below.) The company was already selling carbon offsets on-line and the company's CEO acknowledged that its ocean fertilization activities were as much a "business experiment" as a "science experiment." Climos, another U.S. start-up in the field, is still operational.[48] The CEO of Climos has proposed a "code of conduct" for ocean fertilization experiments to "find effective ways for the science, business and carbon market communities

45. Rachel Petkewich, "Off-Balance Ocean: Acidification from absorbing atmospheric CO2 is changing the ocean's chemistry," Chemical & Engineering News, Volume 87, Number 8, February 23, 2009, pp. 56-58.
46. David Herring, "What are phytoplankton?" NASA Earth Observatory, available online: http://Earthobservatory.nasa.gov/Features/Phytoplankton/
47. Sallie W.Chisholm, Paul G. Falkowski, John J. Cullen, "Dis-crediting Ocean Fertilization," Science, Vol. 294, 12 October 2001, pp. 309-310.
48. www.climos.com

to collaborate."[49] The Ocean Nourishment Corporation,[50] 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 organizations campaigned against the plan. The science of ocean fertilization is increasingly discredited, with experimentation receiving negative reviews from everyone from the Royal Society to the New Scientist, not to mention the Inter-Governmental Panel on Climate Change.[51]

The 191 governments attending the Convention on Biological Diversity adopted a de facto moratorium on ocean fertilization in May 2008. The London Convention and Protocol on ocean dumping has also addressed the issue, and are trying to establish how to define a legitimate scientific experiment.

What's wrong with ocean fertilization?

Phytoplankton are the foundation of the marine food chain. Iron may well stimulate the growth of algae blooms but its potential to capture and eliminate any significant amount of carbon is doubtful at best.[52] The list of potential side-effects is long: oxygen depletion (anoxia) in the deep sea; disruption of marine ecosystems, particularly the food chain; a strong likelihood of increased releases of other GHGs such as nitrous oxide and methane as well as gases such as DMS that form clouds altering weather; potential toxicological impacts such as dinoflagellates in the case of urea fertilization; potential worsening of the problem of ocean acidification. Ocean fertilization could also have devastating impacts on the livelihoods of people who depend on healthy marine systems, most notably fisher folk.

Box 5: Ocean Fertilization – The Planktos Story

Planktos, Inc. was a U.S. start-up company that intended to sow the oceans with iron in order to create plankton blooms that would theoretically sequester CO_2. By early 2007 Planktos was already selling carbon offsets on its web site, claiming its initial ocean fertilization test, conducted off the coast of Hawaii from the private yacht of singer Neil Young, were taking carbon out of the atmosphere. In May 2007, Planktos announced plans to set sail from Florida to dump tens of thousands of pounds of tiny iron particles over 10,000 square kilometers of international waters near the Galapagos Islands, a location chosen, among other reasons, because no government permit or oversight would be required. In efforts to stop Planktos, civil society groups filed a formal request with the U.S. Environmental Protection Agency to investigate Planktos's activities and to regulate them under the U.S. Ocean Dumping Act. In addition, public interest organizations asked the Securities Exchange Commission to investigate Planktos's misleading statements to potential investors regarding the legality and purported environmental benefits of their actions. Hit with negative publicity, Planktos announced in February 2008 it was indefinitely postponing its plans because of a "highly effective disinformation campaign waged by anti-offset crusaders." In April 2008, Planktos announced bankruptcy, sold its vessel and dismissed all employees. It "decided to abandon any future ocean fertilization efforts" due to "serious difficulty" raising capital as a result of "widespread opposition."

49. See Margaret Leinen, "Building relationships between science and business in ocean iron fertilization, July 2008 available at http://www.climos.com/publication.php
50. www.oceannourishment.com
51. Catherine Brahic, "Hungry Shrimp Eat Science Experiment," New Scientist, 25 March 2009, available at http://www.newscientist.com/article/dn16842-hungry-shrimp-eat-climate-change-experiment.html and Royal Society, Geoengineering the climate: science, governance and uncertainty, op. cit.
52. Sallie W.Chisholm, Paul G. Falkowski, John J. Cullen, "Dis-crediting Ocean Fertilization," Science, op. cit

Case Study 2: Artificial Volcanoes – Sulfates 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 twenty million tonnes of sulfur dioxide into the stratosphere and the entire planet cooled 0.4 to 0.5°C. Although the idea of artificial volcanoes was first proposed in 1977,[53] the concept has undergone refinement in recent years.[54] Scientists estimate that a 2% reduction of sunlight could negate the temperature-rise resulting from of a doubling of atmospheric CO2. 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 would be blasted by jets, fire hoses, rockets or chimneys. "Plan B," par excellence, this technique is promoted as an "emergency" measure that would bring results quickly and be inexpensive.

Who's involved?

Blasting particles into the atmosphere is getting more attention than any other geoengineering technology. The U.S. 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.[55] The Novim Group, a new California-based outfit with a mission to present "clear scientific options…without advocacy"[56] issued their first report on climate engineering[57] in August 2009, which focused on artificial volcanic eruptions. Steven Koonin, now Under Secretary for Science at the U.S. Department of Energy, was a lead author. This study proposes an agenda for research, development and deployment.

What's wrong with artificial volcanoes?

Slowing down or stopping the rate of warming via solar radiation management does nothing to change the levels of CO2 in the atmosphere, so symptoms are addressed but not causes. Even advocates admit that stratospheric sulfates have many unknown impacts, but there is research already suggesting:

- There will be damage to the ozone as sulfate particles in the stratosphere provide additional surfaces for chlorinated gases such as CFC's and HFC's 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 be diffused elsewhere.
- It is likely that precipitation levels will be decreased in some regions. Large volcanic emissions of sulfate particles have in the past been accompanied by failed monsoons and extended drought in tropical latitudes.
- Preliminary modeling suggests a rapid rise in temperature if the programme were to be started and then stopped. Such a rapid rise would be more dangerous to life on Earth than a gradual rise.
- Reduced sunlight could undermine the amount of direct solar energy available and disturb natural processes such as photosynthesis by altering the wavelength of incoming sunlight.
- What goes up still (usually) comes down. The tonnes of particles that would need to 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.

53. Budyko, M. I., "Climatic Changes," (Translation of "Izmeniia Klimata," Leningrad: Gidrometeoizdat, 1974), Washington, D.C., American Geophysical Union, 1977.
54. Crutzen, P.J., "Albedo enhancement by stratospheric sulfur injections: A contribution to resolve a policy dilemma?" Climatic Change 77, 2006, pp. 211-219. Matthews, H. D. and K. Caldeira, "Transient climate-carbon of planetary geoengineering," Proc. Nat. Acad. Sci. vol. 104, no. 24, June 12, 2007, pp. 9949-9954 and Wrigley, T.M.L., "A Combined mitigation/geoengineering approach to climate stabilization," Science, Vol. 314. no. 5798, 2006, pp. 452-454.
55. See Eli Kintisch, "DARPA to Explore Geoengineering," Science Insider blog, March 14, 2009, available online at http://blogs.sciencemag.org/scienceinsider/2009/03/exclusive-milit.html.
56. The Novim Group's mission at http://www.novim.org
57. Jason J. Blackstock, David S. Battisti, Ken Caldeira, Douglas M. Eardley, Jonathan I. Katz, David W. Keith, Aristides A. N. Patrinos, Daniel P. Schrag, Robert H. Socolow and Steven E. Koonin, Climate Engineering Responses to Climate Emergencies, 29 July 2009, available online at http://www.novim.org/attachments/037_Novim%20Report%20Final%2007.28.09.pdf

Case Study 3: Cloud Whitening – Albedo Enhancement Below the Stratosphere

The theory

The theory behind cloud whitening is deceptively simple: modify the composition of clouds by injecting them with seawater in order to make them whiter. Injection of salt water theoretically increases the clouds' "condensation nuclei," making them smaller and more reflective.[58] Up to 25% of the world's oceans are covered with thin low-lying stratocumulus clouds (below 2400 meters). Cloud whitening is another solar radiation management technique and, like simulating volcanic eruptions; the technique may reduce the temperature of the atmosphere and the oceans, but would not reduce levels of greenhouse gases. It is imagined that fleets of unmanned vessels would spray mist created from drawn seawater into the clouds above.

Who's involved?

The most prominent scientists advocating for cloud whitening are John Latham from the National Center for Atmospheric Research at the University of Colorado (USA) and Stephen Salter from the University of Edinburgh (UK). Based on "very artificial" modeling techniques that assume "perfect cloud condensation nuclei,"[59] Phil Rasch of the Pacific Northwest National Laboratory argues that seeding the clouds above a quarter to a half of the world's oceans (!) could offset warming by 3 watts per square metre, or, as Latham and Salter hypothesize, "subject to resolution of specific problems," cloud whitening "could hold the Earth's temperature constant as the atmospheric CO2 concentration continues to rise to at least twice the current value."[60] Others have contested these optimistic calculations, however.[61]

What's wrong with cloud whitening?

As recently noted by the American Meteorological Society in its draft statement on geoengineering, proposals that reduce the sunlight reaching the Earth would not only cool the temperature, but "could also change global circulation with potentially serious consequences such as changing storm tracks and precipitation patterns throughout the world."[62] Altering the composition of the clouds over a quarter to a half of the Earth's surface will affect whether pattern and could disrupt marine ecosystems, including bird and plant life. The technique is also inherently transboundary and should require international agreement. For example, models show that one of the most effective areas to target would be off the coast of California and Peru but this may adversely effect coastal rainfall and hence agriculture. Although there have been well-founded rumours regarding plans to experiment with this technology in the Faroes Islands, located between the Norwegian Sea and the North Atlantic, these have not been confirmed and public queries from ETC Group have not provided clarification.[63]

The political and ethical dimensions of climate modification are huge. In a 2005 interview in The Boston Globe, Harvard's Director of the Laboratory for Geochemical Oceanography, Daniel Schrag asked, "Suppose we could control hurricanes, but stopping one requires an incredibly hot day in Africa that would burn up all the crops."[64] Schrag went on, "Let's say you have a mirror in space. Think of two summers ago when we were having this awful cold summer and Europe was having this awful heat wave. Who gets to adjust the mirror?"

58. Panel on Policy Implications of Greenhouse Warming, National Academy of Sciences, National Academy of Engineering, Institute of Medicine, Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base The National Academies Press, 1992.
59. Philip Rasch, C-C Chen, John Latham, "Global Temperature Stabilisation via Cloud Albedo Enhancement," Submission to the National Academies, available on the internet at http://americasclimatechoices.org/Geoengineering_Input/GeoInputHome.html
60. See John Latham et al., "Global Temperature Stabilization via controlled albedo enhancement of low-level Maritime Clouds, Philosophical Transactions of the Royal Society, 366, 2008, pp. 3969-3987.
61. T. M. Lenton and N.E. Vaughan, The radiative forcing potential of different climate engineering options, Atmospheric Chemistry and Physics Dicissions, 9, 1-50, 2009, p. 18-19.
62. "Geoengineering the Climate System: A Policy Statement of the American Meteorological Society," adopted by the AMS Council on 20 July 2009, available online at http://www.ametsoc.org/POLICY/2009geoengineeringclimate_amsstatement.html
63. http://groups.google.com/group/geoengineering/browse_thread/thread/2b6e7fdb90155e4f
64. Drake Bennett, "Don't like the weather? Change it," The Boston Globe, July 3, 2005, online at http://www.boston.com/news/globe/ideas/articles/2005/07/03/dont_like_the_weather_change_it/ (accessed 15 October 2009)

Geoengineering and Intellectual Property Claims

As if restructuring the climate isn't controversial enough, a handful of geoengineers are privatizing the means to do so by claiming patent rights over geoengineering techniques. The politics of patents has always been a divisive issue when it surfaces in different international fora. The UNFCCC is no exception.

In the UNFCCC, governments from the global South generally advocate enhanced mechanisms for technology transfer of useful technologies, including significant financing from developed countries, arguing that existing intellectual property regimes are a barrier to accessing the technologies necessary to mitigate and adapt to climate change. The North advocates – and gets – strong protection of intellectual property rights, arguing that high profits derived from IP drives invention and, eventually, transfer of technologies. The North has also more recently insisted on "enabling environments," a euphemism for corporate-friendly policies at the national level (e.g., liberalized foreign investment and strong domestic IP regimes) as well as easy government access for foreign corporations.

With regard to climate-related technologies, restricting the diffusion of technologies by way of a twenty-year monopoly is clearly counterproductive to enabling urgent action.[65] What IP in this sphere therefore enables is for patent holders to levy lucrative licensing and transfer fees or to press for a more favourable 'enabling environment.' 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 – regardless of ethics, safety or efficacy.

As 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 geoengineering patents granted to Professor Ian S.F. Jones, founder and CEO of Ocean Nourishment Corporation, the claim that his "ocean nourishment" method of dumping urea into seawater will attract fish is accompanied by a claim of legal ownership over any fish subsequently harvested from a urea-fertilized patch of ocean![66] Jones has reiterated this legal claim in correspondence with ETC Group.[67]

Some geoengineering patents also attempt to appropriate and privatize indigenous and traditional knowledge, most clearly demonstrable in the area of "biochar." The technique of burying charcoal in soil was widely practiced by communities throughout the Amazonian Basin before the turn of the first millennium, where it was known as Terra Preta. This technology is now the subject of several patents. (See table below.)

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 Oil, 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.[68] The table below provides a sampling of geoengineering patent applications and issued patents.

65. In a recent discussion paper, researchers from five Asian research institutes, all from countries that comply with the Agreement on Trade Related Aspects of Intellectual Property (TRIPS) – India, China, Indonesia, Malaysia and Thailand – concluded that intellectual property has directly and indirectly hindered technology transfer of climate technologies, even in light of the legal mandate for technology transfer as part of the UNFCCC and the Kyoto Protocol. TERI, Emerging Asia contribution on issues of technology for Copenhagen, New Delhi: The Energy and Resources Institute, 2009.

66. Claim 15 of patent application WO2008131485A1, "Method For Attracting and Concentrating Fish," reads, "A fish harvested using the method of claim 13 or 14."

67. In an email to ETC Group, dated 1 November 2007, Jones wrote, "The Ocean Nourishment Foundation owns the rights to marine protein generated by the patented processes of Ocean Nourishment."

68. Cquestrate web page on open source approach: http://www.cquestrate.com/open-source (accessed 15 Oct 2009).

Table 2: A Sampling of Geoengineering Patents

Patent # or Application #	Title/Explanation	Inventor/Assignee	Publication date
US20090173386A1	Water alteration structure applications and methods / Refers to using an ocean vessel for wave induced downwelling – pushing warm surface waters to lower depths for hurricane suppression, biological enhancement, "recreational area creation," etc.	Bowers, Jeffrey A.; Caldeira, Kenneth G.; Chan, Alistair K.; Gates, III, William H. (yes, a.k.a. Bill Gates); Hyde, Roderick A.; Ishikawa, Muriel Y.; Kare, Jordin T.; Latham, John; Myhrvold, Nathan P.; Medina, Salter, Stephen H.; Tegreene, Clarence T.; Wattenburg, Williard H.; Wood, JR., Lowell L. Searete LLC	July 9, 2008
US20090173386A1	Water alteration structure movement method and system / Refers to the same invention as above, but includes the management of more than one vessel in a system.	Bowers, Jeffrey A.; Caldeira, Kenneth G.; Chan, Alistair K.; Gates, III, William H.; Hyde, Roderick A.; Ishikawa, Muriel Y.; Kare, Jordin T.;Latham, John; Myhrvold, Nathan P.; Salter, Stephen H.; Tegreene, Clarence T.; Wood, JR., Lowell L.Searete LLC	July 9, 2009
WO2009062097A1	Ocean Fertilization Project Identification and Inventorying / Refers to methods to "identify units of carbon sequestered for storage with additional information associated with [ocean fertilization] projects".	Whaley, Dan; Leinen, Margaret; Whilden, Kevin; Climos	May 14, 2009
WO2009062093A1	Quantification and Quality Grading for Carbon Sequestered via Ocean Fertilization / systems and methods for accurately quantifying amounts of carbon sequestered and the minimum periods of time before which the sequestered carbon returned to the atmosphere as CO_2.	Whaley, Dan; Leinen, Margaret; Whilden, Kevin; Climos	May 14, 2009

Patent # or Application #	Title/Explanation	Inventor/Assignee	Publication date
WO2008131485A1	Method For Attracting and Concentrating Fish / Increasing the number of phytoplankton in the ocean by providing a source of nitrogen.	Jones, Ian S.F. Ocean Nourishment Foundation Limited, Australia	November 6, 2008
WO2008131472A1	Carbon Sequestration Using a Floating Vessel/ Refers to fertilizing the ocean with urea to increase the number of phytoplankton.	Jones, Ian S. F.; Rodgers, William; Wheen, Robert, John; Judd, Bruce, Joseph Ocean Nourishment Corporation Pty Limited, Australia	November 6, 2008
WO2008124883A1	Method of Determining the Amount of Carbon Dioxide Sequestered into the Ocean as a Result of Ocean Nourishment/Provides a formula for calculating the amount of sequestered CO_2 for the purposes of "producing tradable carbon credit".	Jones, Ian, Stanley, Ferguson Ocean Nourishment Corporation Pty Limited, Australia	October 23, 2008
EP1608721A1	Method and Device for the Pyrolysis of Biomass / Describes a process for "biochar" – heating biomass and compressing it under pressure.	Meier, Dietrich Klaubert, Hannes	December 28, 2005
WO2009061836A1	Removal of Carbon Dioxide from Air / Removing CO_2 from a gas stream by contacting the stream with a substrate having cations on its surface, where CO_2 from the stream becomes attached to the substrate by reacting with anions, and releasing CO_2.	Lackner, Klaus, S.; Wright, Allen, B. Global Research Technology, LLC	May 14, 2009

Patent # or Application #	Title/Explanation	Inventor/Assignee	Publication date
US20020009338A1	Influencing weather patterns by way of altering surface or subsurface ocean water temperatures / Refers to an ocean "upwelling" system capable of bringing up deeper waters to surface waters.	Blum, Ronald D.; Duston, Dwight P.; Loeb, Jack	January 24, 2002
US6056919	Method of sequestering carbon dioxide / Refers to increasing phytoplankton by applying nutrients to the ocean, specifically, fertilizers "in pulses".	Michael Markels	May 2, 2002
US6200530	Sequestering carbon dioxide in open oceans to counter global warming / Refers to increasing phytoplankton by applying nutrients to the ocean, specifically, fertilizers "in pulses" and in a spiral pattern.	Michael Markels	March 13, 2001
WO0065902A1	Sequestering carbon dioxide in open oceans to counter global warming.	Michael Markels	November 9, 2000
US6440367	Method of sequestering carbon dioxide with a fertilizer comprising chelated iron .	Michael Markels/GreenSea Ventures, Inc.	August 27, 2002

Patent # or Application #	Title/Explanation	Inventor/Assignee	Publication date
US5965117	Water-buoyant particulate materials containing micronutrients for phytoplankton / Ocean fertilization with iron.	DuPont	October 12, 1999
US5992089	Process for sequestering into the ocean the atmospheric greenhouse gas carbon dioxide by means of supplementing the ocean with ammonia or salts thereof.	Ian Jones, William Rodgers, Michael Gunaratnam, Helen Young, Elizabeth Woollahra	November 30, 1999
JP2004148176A2	Method for Suppressing the Amount of Carbon Dioxide Discharged / Refers to the production of biochar "to be embedded in a concrete molded body or the ground."	Maywa Co. Ltd. (Japan)	May 27, 2004
US20040111968A1	Production and use of a soil amendment made by the combined production of hydrogen, sequestered carbon and utilizing off gases containing carbon dioxide / Describes a method for producing biochar.	D. M. Day, James Weifu Lee	June 17, 2004

BOX 6: Best Reasons to Say No to Geoengineering

The perfect excuse: Geoengineering offers governments an option other than reducing greenhouse gas emissions. For many industrial advocates, geoengineering means "buying time"[69] to avoid action on emissions reduction.

Large-scale: For any geoengineering technique to have a noticeable impact on the climate, it will have to be deployed on a massive scale, and any unintended consequences are also likely to be massive. We don't know how to recall a planetary-scale technology.

Unequal: OECD governments and powerful corporations – which have denied climate change or prevaricated for decades (and are responsible for 90% of historic emissions) – are the ones with the budgets and the technology to execute geoengineering's gamble with Gaia. There is no reason to trust they will have the rights of more vulnerable states or peoples in mind.

Unilateral: Many geoengineering techniques could be relatively simple and cheap to deploy, and the technical capacity to do so could be in some hands (of individuals, corporations, states) within the next ten years. It is urgent to develop a multilateral mechanism to govern geoengineering, including establishing a ban on unilateral attempts at climate modification.

Unreliable: Geoengineered interventions could easily have unpredicted consequences due to mechanical failure, human error, inadequate understanding of the Earth's climate, future natural phenomena (such as storms or volcanic eruptions), transboundary impacts, irreversibility or funding failures.

Treaty violation: Many geoengineering techniques are "dual use" (i.e., have military applications). Any deployment of geoengineering by a single state could be a threat to neighboring countries and, very likely, the entire international community. As such, deployment could violate the UN Environmental Modification Treaty of 1978, which prohibits the hostile use of environmental modification.

Commercializing the climate: Competition is already stiff in the patent offices between those who think they have a planetary fix for the climate crisis. If geoengineering's "Plan B" were ever put into motion, the prospect of it being monopolized is terrifying.

Carbon profiteering: No commercial interests should be allowed to influence the research and development of such serious planet-altering technologies. If, as advocates insist, geoengineering is actually a "Plan B" to be used only in a climate emergency, then it should be forbidden to be considered for carbon credits under the CDM or to be used to meet emissions reduction targets.

69. See, for example, "Geoengineering: Giving us the Time to Act," Institute of Mechanical Engineers (UK), August 2009, available at http://www.imeche.org/

Part III:

Reflections and Recommendations: What Next for Geoengineering?

International discourse around geoengineering has thus far been dominated by scientists, technocrats and utopian extremists. While there has been occasional hand-wringing about "governance," critical voices tracking and challenging the champions of a climate technofix have been few and far between. It is urgent and important that the scientific community work with society (including most affected groups, national and even local governments) to monitor and address the climate threats ahead. Yes, science and technology will play a key role in overcoming the climate crisis – but we need a thousand candles of brilliant research rather than a new Manhattan Project. By definition, the practical responses to climate change must change with the latitudes and the altitudes and the ecosystems. While it may satisfy the Nobel interests of scientists to wave magic wands around the globe, it simply takes money away from real solutions on the ground. "Big" Science is going to have to learn to become "diverse" science and to work with Southern governments, local communities, indigenous peoples and peasant farmers already trying to respond to this crisis. Humility will need to replace hubris.

The recommendations of the authors on how to proceed in tackling geoengineering follows in the next few pages.

Technology, Precaution and the UNFCCC Process

Civil society organizations and Southern governments must be extremely vigilant to close off potential "entry points" for climate techno-fixes in the UNFCCC negotiations. It is also extremely important that the outcome of COP 15 include at least a general reference to technology assessment/evaluation that would consider the potential environmental, social and economic impacts of new and emerging technologies for adaptation and mitigation. Where the words "research, development, deployment, diffusion and transfer" occur, "assessment" or "evaluation" should be inserted. At the national level, technology assessment/evaluation should also be integrated into the national technology action plans that will feed into the national adaptation and mitigation plans of each country. Assessment/evaluation could also be done at the international level through the proposed institutional mechanisms such as Technical Panels and included in the global Technology Action Plan.

Geoengineering technologies need to be specifically excluded from the provisions currently under discussion on Transfer of Technology.

ETC Group proposes the following language:

New adaptation or mitigation technologies that involve the intentional and large scale manipulation of the Earth's climate and related systems, such as geoengineering technologies, are excluded from the technology enhancement measures foreseen in UNFCCC Article 4. The precautionary principle should be strictly applied, especially in light of potential transboundary impacts in accordance with principle 21 of the UN Declaration on the Human Environment (Stockholm, 1972). Real world experimentation and deployment of geoengineering without explicit multilateral consensus are prohibited.

Research and Development: Stop Real World Experimentation

The chorus of voices calling for more research into geoengineering technologies is becoming deafening. No longer restrained to marginal extremists, the science academies, the popular and scientific media, some eminent environmentalists, and even politicians and powerful public figures have now called for more research and development into this high-risk Plan B. Many of these voices sound eminently reasonable – even precautionary, arguing that we need research so that we are prepared in the case of a climate emergency. Others will say that it is already too late to solve the climate crisis with mitigation and some form of geoengineering is inevitable so we had best be ready. The consistent message to politicians: pull out your cheque books.

The geoengineering techno-fix, like the climate change crisis it seeks to solve, is a product of industrialized countries where much of scientific research is either done by or influenced by enterprises seeking to make a profit. With all the hubris a planetary scale engineering scheme can muster, the geoengineering lobby wants to get out of the lab and into the world of real-world experimentation. In the absence of democratic debate, clear internationally agreed upon laws, regulations, authoritative bodies and liability provisions, such permission must not be granted.

Therefore, on Resarch & Development:

a) There should be a strict moratorium on all real world experiments and an internationally agreed upon governance framework should be put in place.
b) No patents should be granted to geoengineering technologies, for that would clearly be in conflict with their stated purpose of enabling urgent response measures and provides a perverse incentive to move forward with these risky schemes.
c) Private sector involvement in experimentation or deployment must be prohibited
d) No offsets or carbon credits should be allowed for geoengineering technologies.
e) Participatory research into gaps in current ad hoc international mechanisms and treaties that have an oversight mandate should be undertaken as a matter of urgency.

Assessment of New Technologies

History is replete with examples of technologies that have been sold as panaceas and released into the environment without proper evaluation of their risks and benefits beforehand.[70] Despite years of stated commitment to diffuse "environmentally sound technologies,"[71] definitions remain weak and assessment is ad hoc especially when it comes to social and economic impacts on the poorest and most vulnerable communities.

As we head into the final sprint in Copenhagen, technology stands as the strongest of the four pillars that hold up the negotiations on Long-Term Cooperative Actions. Indeed, with negotiations stymied, diminished expectations all around and the divide between developing and industrialized countries both deep and wide on everything from targets to money to the agreement's architecture, technology is liable to be a centre piece in Copenhagen and beyond. However, a deal on technology without proper assessment provisions could be worse than no deal at all.

At a minimum, such an assessment process should be:

(a) Mindful of the precautionary principle, environmental integrity and the International Bill of Human Rights.
(b) Participatory and accessible to civil society organizations, indigenous peoples organizations and social movements so that people likely to be affected by its deployment can be heard.
(c) Respectful of the principle of local free, prior and informed consent.
(d) Transparent with full public reporting at all stages of the evaluation process.
(e) Independent of corporate interests.
(f) Driven by the countries and peoples interested in obtaining the technology and not by the corporations interested in selling it.
(g) Prior to any decision regarding financial support, which would be contingent upon a positive assessment.
(h) Properly staffed not only with competent scientific personnel, but also with social scientists, civil society and indigenous peoples' representatives and specialists in different regions who are equipped to evaluate the appropriateness of a given technology.

70. Obvious examples include the problems of asbetos, CFCs and more recently, introduction of large-scale agrofuels (see for example www.biofuelwatch.org.uk).
71. Agenda 21 contains an ambitious programme on the transfer of environmentally sound technologies for example. See: http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=52&ArticleID=84&l=en

Governance and Regulation

While geoengineering techno-fixes which manipulate the Earth's climate system are not the only technologies meriting careful *ex ante* assessment, the case for precaution is even stronger due to the high probability of transborder impacts, the concentration of research money and power in a small number of industrialized countries, and the fact that experimentation and deployment will necessarily impact upon the commons: the atmosphere and oceans. It has been well established in the Stockholm Declaration (1972), the Rio Declaration (1992), the precedent-setting Trail Smelter case[72] and in the UNFCCC itself that states are obliged to ensure that "activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction."[73] The widely acknowledged potential for unilateral geoengineering deployment flies in the face of this principle.

There is a tendency for those on the cutting edge – and the profit receiving end – of research and development – to exert control over the debate on geoengineering governance. This can be seen for instance in the recommendation of the Royal Society to have a "voluntary code of practice" developed by the people and corporations who are actually engaged in geoengineering research. It is also illustrated by the proposal by the Climate Response Fund to hold an Asilomar meeting to "have a sort of checklist to be sure that best practices are being followed."[74] Even some of the most vocal proponents for geoengineering have been openly critical of the conflict of interest of the organizers of this proposed meeting. [75]

Ultimately, a new treaty on technology assessment will be required and that could take many years to establish (see Box 7 on ICENT). There are many parallels to be drawn between the challenges we are facing now and the challenges that lead to the drafting and adoption of the Law of the Sea Convention in the 1960s. There too, technological advances forced nations to adopt new international laws regulating the commons. In the meantime, however, the question of what international rules and institutions should regulate geoengineering cannot be left to geoengineers themselves, or to a small group of Annex 1 countries.

Rather, a governance framework needs to be set up that ensure :

a) A full analysis of existing international laws and regulations to identify which bodies and treaties are already mandated to intervene[76] and where the gaps are.
b) An open and transparent international discussion where all countries, particularly those that are most vulnerable to climate change, can be heard.
c) A process that involves civil society organizations, indigenous peoples and local communities at all stages.
d) A strict prohibition of any deployment of geoengineering technologies at least until proper governance mechanisms are in place.

72. This famous case in the 1930 involved a smelter located in Canada causing pollution in the US and determined that the Canadian company was liable for damages in the US. See for example United Nations, Reports of International Arbitral Awards, Volume III, pp. 1905-1982, 2006 available at http://untreaty.un.org/cod/riaa/cases/vol_III/1905-1982.pdf

73. The relevant paragraphs from the Rio Declaration are 2, 13 and 14 and they are echoed in the preamble of the UNFCCC. See also Simon Terry, Restoring the Atmosphere: Dangerous Climate Change and the New Governance Required, Sustainability Council of New Zealand, August 2009 , pp 82 83.

74. The organizers lack both credibility and independence: the key organizer, Dr. Margaret Leinen is the mother of Dan Whaley, CEO of Climos, an ocean fertilization start-up whose "experiments" have met with wide opposition and the chief Scientific advisor, Michael MacCracken, wrote a paper for the World Bank which is positively glowing in its assessment of geoengineering and the need to get on with it. Mike MacCracken, quoted in Eli Kintisch, March Geoengineering Confab Draws Praise, Criticism, Nov 6 2009 http://blogs.sciencemag.org/scienceinsider/2009/11/march-geoengine.html

75. see for example comments by David Keith at http://blogs.sciencemag.org/scienceinsider/full-comment-by.html

76. In terms of international bodies that have direct interest and specific expertise to offer on the question of geoengineering, one can point to, among others, the United Nations Environment Programme, the Office of the High Commissioner on Human Rights, the Food and Agriculture Organization, the United Nations Industrial Development Organization, the United Nations Development Programme, the International Maritime Organization, the United Nations International Strategy on Disaster Reduction, the United Nations Permanent Forum on Indigenous Issues, the United Nations Commission on Sustainable Development, the International Seabed Authority, the United Nations Office for Outer Space Affairs, the United Nations Office for the Coordination of Humanitarian Affairs, UNESCO, World Health Organization, and the World Metrological Organization. Although no international legal framework is specifically equipped to deal with the suite of technologies being contemplated, some are of obvious relevance: The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD Treaty), the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change stand out, but there is also the Law of the Sea Convention, the Montreal Protocol on Substances that Deplete the Ozone Layer, the Long-Range Transboundary Air Pollution Convention and others

Box 7: An International Convention for the Evaluation of New Technologies (ICENT)

Climate change provides an opportunity like no other for the the sound and timely evaluation of new technologies. What is required is an international participatory and transparent process that supports societal understanding, encourages scientific discovery, and facilitates equitable benefit-sharing from new technologies and that results in a legally binding treaty: an International Convention for the Evaluation of New Technologies. Such an instrument could also ensure the conservation of useful, conventional or culturally distinct technologies and promote technological diversification and decentralization as well as access to new potentially life-saving technologies.

The UNFCCC, in collaboration with other multilateral organizations, should work with states to draft and adopt such a multilateral treaty that provides a framework for the assessment (including an early warning system), monitoring and regulation of new and emerging technologies based on the following principles:

- Strict application of precautionary principle
- Respect for international law
- No unilateralism
- Ensuring environmental integrity
- Full consideration of potential negative social or environmental impacts
- Open and transparent process with full civil society participation
- Fair, full and equitable representation and participation of developing countries
- Involvement of relevant UN treaty bodies

Southern governments will welcome the early warning, open assessment, and facilitated access elements of the initiative. Some risk assessment and regulatory expenses would be secured at the international level. The North – including scientific organizations, industry, and governments – will welcome an end to unpredictability and societal distrust and the establishment of a generalized, non-crisis approach to technology diffusion. Civil society will welcome a transparent and participatory process with both early listening and technology conservation/diversification potential. Everyone stands to gain by such an instrument and the absence of one is a threat to us all.

Elements of ICENT: A possible structure for such a convention could look like the following: The member states would form a Conference of the Parties to the Convention (COP). The COP would be supported by a modest Secretariat and enabled by a Bureau comprised of regionally- determined representative states. The COP would meet biennially while the Bureau would meet semi-annually. Two expert permanent committees, consisting of all members, would convene annually and would ordinarily report to COP through the Bureau.

This new treaty body would have a Committee on Technology Assessment (COTA) that will identify significant new technologies; establish appropriate evaluation processes for each identified technology; review progress; and recommend each technology's dismissal, delay or diffusion to COP.

COTDAC, the Committee on Technological Diffusion and Conservation, would promote the conservation and enhancement of conventional/cultural technologies; encourage technological diversification; promote public participation and understanding; and support the diffusion of appropriate new technologies. COTDAC would have the financial resources to support national capacity building in science and technology, and to encourage broad and equitable dissemination.

Although it would function financially and politically as an independent nongovernmental agency, ACSENT (Advisory Committee for the Socio-Economic and Ecological Evaluation of New Technologies) would be a centre of scientific excellence dedicated to the independent monitoring of science and technology and would have the necessary resources to offer the international community an alternative or additional perspective on technologies and their dissemination.

The Role of Civil Society

Civil society organizations have a vital role to play in this debate. Already indigenous peoples, popular organizations, international NGOs and women's groups have expressed their opposition to geoengineering schemes, yet have been excluded from official processes to date.[77] While environmental groups have good reason to be alarmed at the pace of climate change, they must not allow this panic to push them into a corner where they accept a treatment that is as harmful as the disease they fight. Climate change must not be examined in isolation from other global crises – poverty, hunger, species extinction, biodiversity loss, ocean acidification, war – or the solutions that will be envisaged are liable to exacerbate other problems.

Civil society organizations should:

a) Work for a ban on any real-world experimentation and ensure the strict application of the precautionary principle.
b) Expose the overt and covert interests of geoengineering proponents, in particular private sector involvement
c) Ensure that marginalized voices are heard and that climate change is not seen in isolation from equally important crises
d) Demand accountability from governments, corporations and scientists who are actively considering or promoting these technologies.

77. See for example the Anchorage Declaration of Indigenous Peoples on Climate Change, April 2009 available at http://www.indigenoussummit.com/servlet/content/declaration.html

As the climate crisis become ever more apparent, as new science indicates an even more serious situation, and as international climate negotiations prove disappointingly slow and unambitious, the attraction of quick, techno-fix solutions seems to be gaining ground. Geoengineering – the large-scale intentional modification of oceans, atmosphere and land to counter the effects of climate change – has over only a few years gone from the realm of science-fiction to now being discussed by established scientists, policy-makers and media. Still, most people, even those working on climate change, are largely unaware of what is going on.

This report, prepared by the ETC Group for the Swedish Society for Nature Conservation, outlines the politics and interests in play, and the many risks and concerns associated with geoengineering. It argues for precaution, technology assessment and the need for civil society to monitor both the technologies and those favoring them. If not, the world run a serious risk of choosing "solutions" that turn out to be new global problems.

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The Swedish Society for Nature Conservation is an environmental organisation with power to bring about change. We spread knowledge, map environmental threats, create solutions, and influence politicians and public authorities, at both national and international levels. Moreover, we are behind one of the world's most challenging ecolabellings,

"Bra Miljöval"(Good Environmental Choice). Climate, the oceans, forests, environmental toxins, and agriculture are our main areas of involvement.

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