



UNEP Global Environmental Alert Service (GEAS)

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MAY 2011

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Thematic Focus: Climate Change, Environmental Governance

Geoengineering to Combat Global Warming

As average temperatures continue to climb because of climate change, some scientists are proposing quick fixes to buy time. Recent overviews of geoengineering schemes show that tampering with large-scale natural systems can have unintended side effects and their environmental, social and legal implications need to be addressed.



Geoengineering to Combat Global Warming



Credit: NASA

Why is this important?

Geoengineering is the calculated large-scale manipulation of the environment. It was first introduced in the 1830s with proposals to sow clouds to stimulate rain, and later on, to modify the path of hurricanes by seeding them with silver iodide. Most recently, geoengineering methods have been proposed, in addition to mitigation and adaptation, to counteract anthropogenic climate change (The Royal Society 2009).

One of the attractions of geoengineering is the potential for some planetary schemes to remove CO₂ from the atmosphere. Examples include the large-scale building of artificial trees (machines that remove CO₂ from the atmosphere, as do real trees, but capture it in sorbent material (the machine's "leaves") for removal and burial); and algae-coated buildings (strips of algae are placed on the outside of buildings to absorb CO₂ through photosynthesis, and are harvested and used as biofuel in a solution that avoids the use of agricultural land) (IMECHE 2009). One of the earliest ideas to remove carbon from the atmosphere was large-scale ocean fertilization to stimulate the growth of marine organisms that absorb carbon (The Royal Society 2009)(Box 2). Other proposed climate-change solutions attempt to reduce the amount of solar radiation absorbed by the Earth's climate system, such as making the world's buildings extremely reflective, for example.

Another idea is to inject sulphur dioxide into the stratosphere about every 30 years (Wigley 2006). Sulphate particles provide nuclei for cloud formation that reflects light, helping to cool surface temperatures. Its precedent is a natural event that cooled global temperatures by some 0.7-0.9 degrees between 1992 and 1993. When Mount Pinatubo in the Philippines erupted in 1991, it spewed more than 15 million tonnes of sulphur dioxide 33 km into the stratosphere, causing a dust cloud that reflected sunlight and cooled the climate over several years. Box 1 (next page) lists examples of climate-altering technologies under the two categories.

Box 1: Geoengineering technologies to address climate change

Solar reflection:

- Enhancing surface brightness (painting roofs and other surfaces white)
- Enhancing cloud brightness (by spraying them with sea-water droplets to increase their cooling effect)
- Increasing stratospheric aerosols (injecting sulphur dioxide into the stratosphere to help form reflective clouds)
- Placing reflectors in space

Carbon dioxide removal:

- Afforestation, reforestation and avoidance of deforestation (because trees sequester carbon)
- Algae-coated buildings (the algae absorb carbon dioxide through photosynthesis)
- Biochar (converting agricultural waste into a form of charcoal that holds carbon and retains nutrients and water in soils)
- Enhancing weathering of carbonate or silicate rocks (which removes CO₂ from the atmosphere as the rocks disintegrate)
- Air-capture of carbon dioxide (such as artificial trees)
- Pumping liquid CO₂ into rocks or the deep sea
- Ocean fertilization (supplying nutrients to enhance the growth of tiny plants that absorb CO₂)

Source: Williamson 2011, Bracmort and others 2011, Robock 2010

Geoengineering for climate change has attracted interest as a way to gain some time while the world struggles to reduce greenhouse gas emissions enough to keep the planet from warming to a dangerous degree. Even if greenhouse gas emissions were drastically reduced today, the momentum of past emissions means the impacts will still be felt for hundreds of years, making geoengineering sound like an attractive stop-gap (Williamson 2011). But such large-scale tampering with natural systems has generated concern and controversy for a number of reasons. The feasibility and effectiveness of these interventions are uncertain and there are unknown risks to the environment and humans. In addition, although they may slow global climate change, they could have serious regional and local impacts. Injecting the stratosphere with sulphur, for example, would likely exacerbate drought in Africa and Asia, affecting millions of people (Robock and others 2008). In effect, in 2007, the IPCC cautioned that geoengineering technologies, such as ocean fertilization or injecting material into the upper atmosphere to block sunlight, remain largely unproven, risk uncertain side-effects and have not been the subject of reliable cost estimates (IPCC 2007).

In addition, many observers and environmental groups believe that presenting geoengineering as a potential solution to climate change could divert attention and resources from mitigation and adaptation efforts (Wallace and others 2010). They also deem that curbing fossil fuel use and developing renewable energy sources should remain the primary focus of efforts to address climate change (Brumfiel 2009).

What are the findings and implications?

There have been two important recent assessments of geoengineering for climate change. In late-2009, the Royal Society, Britain's foremost scientific organization, released its first analysis of geoengineering for climate change. The report assessed schemes related to protecting and enhancing carbon sequestration by land sinks; using biomass to sequester carbon; enhancing natural weathering processes to remove CO₂ from the atmosphere; directly capturing CO₂ from ambient air; and ocean fertilization (the latter is illustrated in Box 2). It assessed them for their effectiveness, affordability, timeliness and safety. Its key conclusions are that geoengineering cannot provide an easy or acceptable alternative to reducing greenhouse gases, which is the safest and most predictable way to attenuate climate change. To potentially help mitigate future climate change, geoengineering should undergo more detailed research and analysis; and that Parties to the UNFCCC should make increased efforts to mitigate and adapt to climate change (The Royal Society 2009).

Box 2: Ocean fertilization with iron

The idea of fertilizing the ocean with iron or other nutrients stems from the understanding that microscopic marine plants absorb CO₂ through photosynthesis. As these plants sink deeper in the water column, they take CO₂ from the surface and release it further below.

Over thousands of years, most of the CO₂ currently being released to the atmosphere will be transferred to the deep sea. The limiting factor in this system is the supply of nutrients available for net algal growth at the ocean's surface (The Royal Society 2009). Thus, ocean fertilization is a geoengineering proposal that involves introducing nutrients to the ocean's surface to activate algal growth (Wallace and others 2010).

The Royal Society notes that the effects of iron fertilization have been studied in a series of about 12 small-scale test releases over the past 15 years, over areas of about 10 km². They resulted in predicted algal blooms, but other limiting factors, such as respiration or grazing by zooplankton, moderated the impacts. It found that the increased algal blooms from injecting iron in the ocean would absorb relatively little carbon and would consume enormous amounts of oxygen, potentially causing oceanic "dead zones." It pointed out other potential dangerous side effects, such as suppressing Asian monsoons or modifying the oceans' acidity (The Royal Society 2009).

Another recent assessment looked specifically at ocean fertilization. In 2010, the Intergovernmental Oceanographic Commission (IOC), which is part of UNESCO, published a timely overview of the scientific understanding of ocean fertilization. The report, based on a review of the published literature and extensive consultations involving independent scientists from seven countries, is aimed at policy makers. It noted that the small-scale and short-term nature of ocean fertilization research prevented the acquisition of knowledge about the impacts of iron fertilization on zooplankton, fish and seafloor biota, and measures of the magnitude of carbon export to the deep ocean. The IOC's most salient finding is that even over one-hundred years, very large-scale fertilization would remove only modest amounts of CO₂ from the atmosphere. Recent models have calculated the cumulative amount of CO₂ sequestered in a massive fertilization scenario over 100 years. It is in the range of 25-75 Gt (gigatonnes) of carbon. By comparison, in a business-as-usual scenario of fossil-fuel burning for the same period, the cumulative emissions would be about 1 500 Gt of carbon (Wallace and others 2010).

The IOC report also noted the dearth of information on the effects of fertilizing low nutrient regions and that there have been no experimental studies at the geographical and temporal scales necessary to understand the potential for commercial applications. It cautioned that monitoring is essential to assess the total benefits and impacts but that they would be very difficult and costly to investigate (Wallace and others 2010).

The potential climate change mitigation capacity and the short and long-term risks to humans and ecosystems and their distribution over the planet and among groups of people are different for each geoengineering proposal. For example, although direct CO₂ removal would have global benefits, there would be local impacts; and while reflecting sunlight would reduce the Earth's temperature, it could also adversely affect climate and weather patterns as well as change ecosystem structure and functions, and its impacts would not be the same for all nations and peoples (AMS 2009). The implications of most geoengineering schemes are enormous and include unknown risks and unintended side effects; probable irreversibility; wide-spread impacts on globally shared resources affecting people who may disagree with the actions; and the potential for one group of people to benefit at the expense of another (Williamson 2011). Thus, there are many legal, ethical, diplomatic and security concerns to overcome before these schemes can be considered solutions.

Both the Royal Society and IOC reports note the urgency of addressing the environmental, social and legal implications of such geoengineering schemes. The former recommended that international regimes review all preliminary research projects and develop rules for geoengineering uses. In 2008, the Convention on Biological Diversity (CBD) upheld the precautionary principle by declaring that no further ocean fertilization should be conducted in non-coastal waters until a global regulatory mechanism could provide strong scientific justification. Recently, the London Convention and London Protocol (LC/LP) began developing such a regulatory framework (The Royal Society 2009). In late-February 2011, 12 universities and research centres around the world came together to form an international consortium to study the capacity of iron to remove atmospheric carbon dioxide. Consortium members have signed a Memorandum of Understanding agreeing to follow the London Convention/London Protocol's internationally accepted practices (ISIS Consortium 2011).

Finally, at the CBD's tenth biennial meeting held in Nagoya, Japan, in 2010, member nations reinforced the 2008 moratorium on ocean geoengineering and the precautionary principle, declaring that "no climate-related geo-engineering activities that may affect biodiversity should take place until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts" (CBD 2010).

Reducing emissions and geoengineering are not mutually exclusive activities; in addition to strict carbon controls, it would be wise to simultaneously engage in controlled geoengineering experiments to explore the potential for short-term gains. Scientists need to consider the environmental risks of geoengineering, however, and the public and decision makers need to participate in discussions about the ethical, social, and geopolitical constraints of these new technologies (Williamson 2011).

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