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Climate Geoengineering: A Growing Foreign Policy and Public Perceptions Challenge, but Currently a Low Technical Threat (b)(3)

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Key Findings (b)(3)

At least 20 countries are studying climate geoengineering to counter the effects of greenhouse gas emissions, and concerns regarding unregulated research of potentially risky technologies will probably lead to calls for international governance and transparency agreements. Interest in geoengineering is likely to accelerate as mitigation and adaptation efforts fall short of what the global scientific community says is necessary to prevent severe effects from climate change.[1]

- Geoengineering refers to intentional measures to influence the earth's climate to counter the effects of global warming. Proposed methods include reflecting additional radiation to cool the earth's surface and technologies to artificially remove carbon dioxide from the atmosphere. Many scientists are opposed to geoengineering and stress that the risks are diverse with insufficient research to reliably estimate the type or magnitude of local or global side effects.[2]

- open press reports[4 5 6 7] reveal that more than 120 scientists around the world—with nearly half based in the United Kingdom and about two-thirds in Europe—are studying geoengineering. (b)(1) (b)(3)

- Almost all open research is computer or lab based, with only two known small field experiments conducted in 2009 with German, Indian, and Russian government support, and one planned for late 2011 in the United Kingdom.[8 9 10 11 12 13] (b)(3)

As geoengineering discussions and research gain momentum, public attention to the issue and suspicion of countries pursuing geoengineering research is likely to increase, particularly if research is seen as lacking international consensus or having a military dimension. Proactive US support for transparent international governance would probably allay public fears and suspicions about Western geoengineering research.[14 15 16]

- multiple parties to the Convention on Biological Diversity and the London Convention/Protocol on Marine Dumping have urged regulation or bans on all geoengineering activities, (b)(1) (b)(3)

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Scope Note This paper seeks to establish a baseline assessment of the emerging field of climate geoengineering, referred to as geoengineering in this assessment. (b)(3)

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Note that the civil engineering field also called geoengineering concerns large-scale projects, such as tunnels and dams, and is unrelated to climate modification. (b)(3)

Climate Geoengineering: A Growing Foreign Policy and Public Perceptions Challenge, but Currently a Low Technical Threat (b)(3)

As global efforts to reduce greenhouse gas emissions continue to lag behind UN targets for limiting dangerous global climate change, interest in geoengineering research is likely to continue gaining momentum. Geoengineering could be implemented unilaterally or with something less than universal consensus, raising concerns and calls for international governance and regulation of research. The United States will increasingly be engaged in governance discussions in international forums and will probably encounter international suspicion about US geoengineering research.

- Geoengineering refers to intentional measures to influence the earth's climate to counter the effects of global warming. Proposals include methods to reflect additional radiation, for example, by adding sulfate aerosols to the atmosphere or making clouds more reflective, and technologies such as ocean fertilization or air capture that could remove carbon dioxide (CO_2) from the atmosphere (see foldout).

- Many countries have researched and used rain enhancement or suppression for decades, but weather modification programs generally have local effects whereas geoengineering aims to influence climate on a global scale.

Growing Interest in Geoengineering

Scientists, economists, and international English-language media are increasingly discussing geoengineering as a relatively low-cost, last-resort option to prevent serious climate change effects as international efforts to limit global emissions continue to stall. UN Framework Convention on Climate Change (UNFCCC) Chief Christina Figueres in June 2011 warned that if climate treaty negotiations do not make progress the world may require more powerful technologies to capture emissions, which she described as "risky territory."[22]

- Global-scale geoengineering was first mentioned as a policy option to counteract increasing carbon dioxide as early as 1965,[23] but experts comment that the issue has gained more public attention in recent years.[24 25] A survey of international wire service reporting shows scant mention of geoengineering before the mid-2000s, increasing to dozens of articles per year during 2009-11.[26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50]

- Scientists who advocate geoengineering research frame it as a potential option if the world faces a "climate emergency," arguing that research to determine effectiveness and side effects is necessary to inform any potential discussions of geoengineering use.[51 52 53]

- Most experts and scientific consensus reports agree that geoengineering is only viable as a short-term measure until permanent greenhouse gas reductions can be made, because of unknown side effects and concerns that interruption of a geoengineering program could cause sudden and severe climate shocks.[54 55 56 57 58 59] (b)(3) (b)(3))

According to a survey of open literature, at least 122 foreign researchers in 20 countries are investigating geoengineering, primarily using computer modeling with a handful of known small-scale field

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This assessment was prepared by the Office of Transnational Issues. Comments and queries are welcome and may be directed to the Chief, CIA Center on Climate Change and National Security, OTI, (b)(3)

experiments. The majority of computer-based work adapts existing climate models to simulate proposed geoengineering measures.[60]

German and Indian governmental institutes cosponsored a $4.5 million ocean fertilization experiment in 2009, which uncovered a previously unknown biological feedback that prevented any significant carbon sequestration, according to open-source reports.[66]

- The Intergovernmental Panel on Climate Change (IPCC) plans to include a discussion of geoengineering science, risks, and uncertainties in the 2013 Fifth Assessment report.[67] CIA analysts assess inclusion in the premier international review of climate change science reflects the mainstreaming of geoengineering research.

High Uncertainties and Unknown Risks

Many scientists stress that because geoengineering research is at such an early stage they cannot reliably estimate the effectiveness of proposed techniques, potential biological or climatic side effects, regional distribution of effects, or possible unintended consequences. A US National Research Council report on weather modification noted that while human activities such as pollution are known to influence the climate, there is insufficient experimental support for claims that specific interventions can reliably produce desired weather outcomes.[68]

- Follow-up studies to the 2009 German-Indian experiment indicated that iron fertilization can trigger production of small quantities of neurotoxins, according to open-source reports.[69] [70] [71] The 2007 IPCC report recommended further research given ocean fertilization's uncertain carbon sequestration benefits and potential harm to ecological communities.[72] (b)(1) (b)(3)

- According to studies of past volcanic eruptions and computer modeling, stratospheric aerosols could strengthen northern hemisphere weather cycles, reduce precipitation globally, modify the Asian and African monsoons, and hamper recovery of the ozone layer.[73] Cloud brightening can be conducted only in specific areas and hence would most likely have an impact on regional weather patterns, potentially either increasing or decreasing precipitation depending on the technique and season.[74] (b)(3)

Public Awareness Limited, but Controversial Among Those Knowledgeable (b)(3)

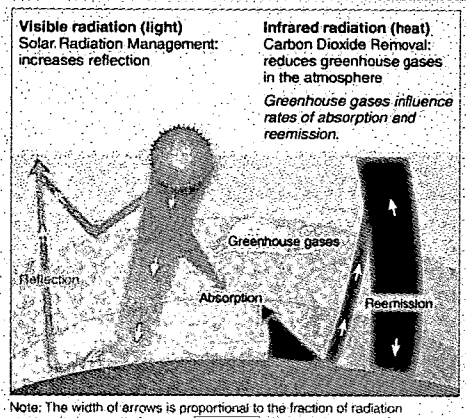
Among the scientists, activists, and media following the issue, geoengineering is controversial because of sensitivities about humans intentionally manipulating global weather and disagreements about the appropriate way to tackle climate change, but it is difficult to assess the level of public awareness, particularly in the developing world. During the past few years, the issue has gained regular attention in international English-language media,[75] [76] [77] [78] [79] [80] [81] [82] [83] [84] but is not a major topic of discussion in the press and blogs in China, Mexico, the Middle East, Russia, South Africa, and South Asia, (b)(1) (b)(3)

Geoengineering: Methods To Counter the Effects of Greenhouse Gases

Geoengineering refers to intentional steps to influence the earth's climate to counter the effects of global warming. The two classes of geoengineering are: Solar Radiation Management (SRM) to reflect radiation and thus cool the earth's surface and Carbon Dioxide Removal (CDR) to artificially remove additional CO_2 from the atmosphere.

Radiation from the sun is absorbed, reflected, and reemitted both at the surface and at different layers in the atmosphere.

Geoengineering seeks to change these energy balances to compensate for human emissions of greenhouse gases.



Note: The width of arrows is proportional to the fraction of radiation absorbed, emitted, or reflected.

Carbon Dioxide Removal (CDR)

CO_2 removal from the atmosphere directly addresses the problem of CO_2 emissions accumulation but would require several years before climate effects would be observed. Some CDR techniques have significant logistical challenges in obtaining materials or sequestering the removed CO_2, and some are energy intensive.

- **Large-scale ocean fertilization**—boosting the levels of nutrients in the ocean to increase the activity of small CO_2-absorbing organisms such as algae—was once considered a leading candidate for geoengineering, but field research tests suggested carbon reductions would be minimal, and fertilization could lead to unintended chemical consequences including the production of toxic acids.
- **Air capture and storage**, which would directly remove CO_2 via air scrubbers, faces the same energy cost and storage location challenges as carbon capture and storage at power generation plants. Enhanced rock weathering or liming the ocean could speed removal of CO_2 from the air but would pose substantial logistical challenges in mining and disposing of large quantities of rock.
- **Afforestation, reforestation, and biochar production** could be considered geoengineering techniques as managed programs to reduce greenhouse gases in the atmosphere, but they are generally considered land management and agriculture issues, and all would mean more competition for land use.

Solar Radiation Management (SRM) (U)

SRM techniques control the amount of radiation that reaches the earth's surface and could be deployed quickly if developed to an operational stage. Many SRM techniques are considered risky due to potential climatic side effects and because they would require continuous effort; any disruption to SRM programs could cause a severe climate shock as the earth's radiation balance would quickly rebound. Also, because SRM does not reduce CO_2 levels, some aspects of climate change, such as increasing ocean acidification, would continue unabated.

- **Cloud whitening methods** would spray aerosols such as saltwater mist to promote more condensation, making clouds more reflective. Cloud whitening is considered the most promising geoengineering technology today. However, it would be applied unevenly where climatic conditions permit, particularly over tropical regions. This could result in local weather effects, such as severe drought and temperature changes, because it could alter the distribution of clouds in unpredictable ways.
- **Stratospheric aerosols**, particularly sulfur, could be sprayed at high altitudes to reflect additional radiation. Sulfate aerosols are one of the most frequently discussed options for SRM. The 1991 Mt. Pinatubo volcanic eruption provided a well-studied natural analogue, with volcanic sulfate aerosols lowering the global temperature approximately 0.5 degree Celsius in the year following the eruption, according to scientific studies. However, precipitation significantly decreased following the eruption, as did stratospheric ozone. Stratospheric aerosols probably pose the greatest risk for unilateral deployment because countries could deploy them quickly with lower costs and fewer technical challenges than other options, according to the same study.
- **Albedo enhancement** ideas include painting roofs white, covering deserts with white sheeting, developing crops or other plants with more reflective leaves, or engineering ocean bubbles that would create a more reflective ocean surface. These options are less studied because of concerns about weather or ecosystem side effects or questions about cost effectiveness. **Space sunshades** could be placed in orbit to reflect additional sunlight but would be one of the more expensive options.

Stratospheric aerosols and nutrient seeding in the oceans are actively discussed in the international research community and have a cost, development detectibility, deployment speed, and potential climate impact.

Selected Techniques	Potential Impact	Cost	Development Detectability	Deployment Speed	Selected Countries With Ongoing Research[a]
Solar Radiation Management					
Stratospheric aerosols	High	Low	High	High	Australia, Austria, Canada, France, Germany, Israel, Japan, Russia, Saudi Arabia, Switzerland, UK
Cloud whitening—marine vessels	High	Low	Medium	Low	Russia, Norway, Spain, UK
Carbon Dioxide Removal					
Biochar production	Medium	Low	Medium	Medium	Australia, Brazil
Air capture & storage	High	High	Medium	High	Australia, Canada, Germany, UK
Nutrient addition to the ocean	Medium	Low	Low	Medium	Canada, Germany, India, UK

Criteria used for ranking proposed geoengineering techniques, with rankings determined by experts in the field. Impact is measured in radiation units of watts per square meter (W/m^2).

	High	Medium	Low
Potential Impact	>2.0 W/m^2	0.5-2.0 W/m^2	<0.5 W/m^2
Cost	>$50 billion/year	$10–$50 billion/year	<$10 billion/year
Development detectability	Ratings are based on scale of market impact, experiment observability, development footprint, and whether multiple countries must coordinate implementation.		
Deployment speed	<3 years	3–5 years	>5 years

[a]According to open industry and press information. Not necessarily a complete list.

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Weather Modification: Related Technology

At least 24 countries, including China and Russia, have weather modification programs, according to a World Meteorological Survey done in 1999,[90] [91] [92] and these technologies and expertise could probably be applied to some geoengineering techniques. If a country felt weather modification was a practical or public relations success, this could build confidence for investments in geoengineering research.

- Chinese bloggers accused the government's weather modification program of causing or exacerbating unusually early and heavy snowfall in 2009, according to press reporting.[99] China publicly touts the program as ensuring good weather for key national events such as the 2008 Olympics.[100] [101]

- Only a few scientists and economists argue that geoengineering would be an inexpensive complement or alternative to pricier greenhouse gas mitigation and clean energy measures.[103] [104] [105] [106] [107] However, most experts argue that geoengineering should be considered only in the event of a "climate emergency,"[108] [109] and as a short-term option it cannot replace greenhouse gas reductions in mitigating climate change risks.[110] [111] [112] [113] [114] [115]

- A small geoengineering-focused Canadian NGO railed against geoengineering events at the 2009 Copenhagen meeting, saying industrialized countries cannot be trusted to attempt a climate "techno-fix" that would have remotely equitable impacts, and arguing that voluntary scientific self-regulation is inadequate and preempts a public discussion about whether geoengineering should be pursued at all.[116] (b)(3)

- The UK National Environmental Research Council (NERC) held several open forums on geoengineering in 2010 attended by capacity audiences who had low initial awareness of the issue, were broadly opposed to intentional interference with the climate, but who ultimately gave cautious support for research and engaged constructively in discussions about appropriate governance and regulations. (b)(1) (b)(3) (b)(1) (b)(3)

Possible Motivations for Geoengineering (b)(3)

If research progresses to reduce some of the uncertainties currently endemic to the field, countries or nonstate actors could be motivated to develop a program to reverse damaging climate change, or as a publicity stunt to try to galvanize the international debate about climate change mitigation. Worsening climate conditions—including recurring weather shocks or pending climate tipping points such as the Asian monsoon—could drive any of the more technically advanced nations to accelerate geoengineering research and development. (b)(1) (b)(3)

- A country that feels under mortal threat from climate change—such as a small island state—may grow desperate if it perceives global emissions reductions are inadequate and might independently attempt a program or partner with a wealthy nation or donor in a public relations bid to push the international community toward more aggressive climate actions. (b)(3)

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- The 1976 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification prohibits any military or hostile weather modification that causes widespread, long-lasting, or severe effects as a means of injury to any party, and has been signed by 75 nations, including China, Japan, Russia, and the UK.[121] [122] The definition of environmental modification could encompass some geoengineering techniques, although the Convention permits environmental modification for peaceful purposes. (b)(3)

International Governance Under Discussion

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Calls for governance of geoengineering are growing from governments concerned about the issue, researchers seeking legal guidance for further work, and activists opposed to geoengineering. Some experts suggest that modification of existing environmental protection treaties will be the most feasible route for international governance initiatives, possibly using multiple instruments to cover different types of geoengineering technologies.[123] [124] [125]

- The Convention on Biological Diversity (CBD) and the London Convention/Protocol on Marine Dumping both hosted contentious debates regarding regulation of ocean fertilization in meetings in 2008 and 2010,[130] [131] The 2008 nonbinding CBD resolution was widely viewed as a de facto moratorium on ocean fertilization and oceanographers were concerned this could effectively restrict scientific research, but 2011 CBD language would not restrict US research interests.[135] [136] (b)(1) (b)(3)

- The 2010 Asilomar Conference—attended by 165 experts in the field—concluded that transparency, public and intergovernmental engagement, and governmental oversight are essential to responsible conduct of geoengineering research.[137] The UK Royal Society likewise noted in 2009 that there is no international treaty or institution with a (b)(1) (b)(3)

Potential Incentives for Private Industry if Carbon Credits Permitted

A few companies are exploring geoengineering options to accelerate carbon removal from the atmosphere, probably with the intent of selling carbon credits on international exchanges such as the EU Emissions Trading System (ETS) or the Kyoto Protocol's Clean Development Mechanism (CDM), or possibly to contract their geoengineering services to interested governments.

- Multiple companies have explored developing ocean fertilization to sequester carbon, a technology some hoped would ultimately be certified to generate carbon offset credits.[138] [139] [140] [141] [142] None of these companies reached a level of development sufficient to pursue accreditation, and the London Convention/Protocol in 2008 approved a strong but nonbinding resolution that restricts commercial ocean fertilization

- Europe's ETS market was valued at about $100 billion in 2010, and the CDM was worth about $20 billion, according to press reporting, although the market value slid in 2011 because of continuing economic weaknesses and oversupply of credits in the market.[144] [145]

sufficiently broad mandate to regulate geoengineering activities and said there is an immediate need for established frameworks to deliberate and regulate geoengineering research.[146]

Outlook: Increasing Attention and Accusations

Growing discussion and research of geoengineering will probably lead to greater public attention and controversy, particularly if research is seen as lacking international consensus or having a military dimension.

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- An article in the official daily newspaper of the Russian Ministry of Defense included two viewpoints on whether the 2010 heat waves and wildfires were the result of a US "climate weapon."[148]

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We assess there is also high potential for North-South tensions regarding geoengineering in the absence of a broadly accepted governance regime. The United States may face accusations of delaying climate mitigation in favor of geoengineering solutions, ignoring the potential negative side effects on others.

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- More than 125 environmental, development, and human rights groups from 40 countries sent a letter protesting the IPCC expert meeting on geoengineering held in June 2011 in Lima, Peru, saying the prospects for negative consequences for the global south were too high to consider geoengineering.[150] The letter urged broader participation from civil society groups in geoengineering deliberations to counterbalance "the more prominent and extreme positions of some northern scientists."

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Support for Governance Would Probably Allay Concerns

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Proactive US support for governance initiatives requiring well-regulated and transparent research could allay fears about uncontrolled geoengineering and prevent a public backlash against climate research efforts in related but benign areas.

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Public concerns might be assuaged by an agreement among technically advanced nations to pledge transparency in any research and funding, establish a scientific risk evaluation panel for proposed field tests, and designate the UN Security Council or similar international body as the arbiter of any geoengineering deployments.

- Multiple groups including the Asilomar Conference and UK Royal Society have called for scientific organizations to establish a code of practice for researchers to promote open and collaborative research, risk management, and public engagement.[153] [154] However, these groups also stress that governmental involvement will be necessary, particularly when considering any geoengineering research that could have cross-boundary effects. (b)(1) (b)(3) (b)(3)