Geoengineering Research: A Necessary Part of a Robust Climate Response Strategy

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In their 1957 paper on carbon dioxide and climate, Roger Revelle and Hans E. Suess wrote: "Human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future." Nearly six decades later, the same uncontrolled "experiment" continues unabated, while new ones — intended to address the effects of humanity's atmospheric footprint — are being proposed. Multiple concepts for directly and deliberately manipulating Earth's climate system, collectively referred to as "geoengineering," are being considered as potential responses to climate change.

The intentional application of geoengineering is complex and fraught with issues spanning science, technology, politics, economics, law and ethics. Yet, given the acceleration in carbon dioxide emissions from fossil fuels (an unprecedented 5.6 percent increase in 2010) and continued indications of impacts to Earth's atmosphere, land, cryosphere and oceans, there is a credible risk of a scenario with untenable consequences. Given that carbon dioxide has a lifetime of thousands of years in the atmosphere, the risk is compounded, as any impacts will be largely irreversible on human timescales.

Given the stakes, climate risk management should include an informed evaluation of potential contingency actions such as geoengineering before committing to or rejecting them completely.

What Is Geoengineering?

The term geoengineering encompasses many different techniques. Some, such as chemically extracting carbon dioxide from the air, have been relatively well studied and are arguably low risk. In such cases, developing low-cost technologies that could be widely deployed could lower the risk of irreversible climate change and ocean acidification.

Other geoengineering schemes are considerably higher risk, given the uncertainty of how they will work and the risk of unintended consequences that could exceed the impacts of inaction. Such proposals include fertilizing the ocean with iron filings to create giant algal blooms in the hopes of soaking up carbon dioxide from the air and various methods that seek to manage incoming solar radiation — for example, injecting large quantities of light-scattering aerosols into the stratosphere or seeding marine clouds to increase Earth's albedo (reflectivity).

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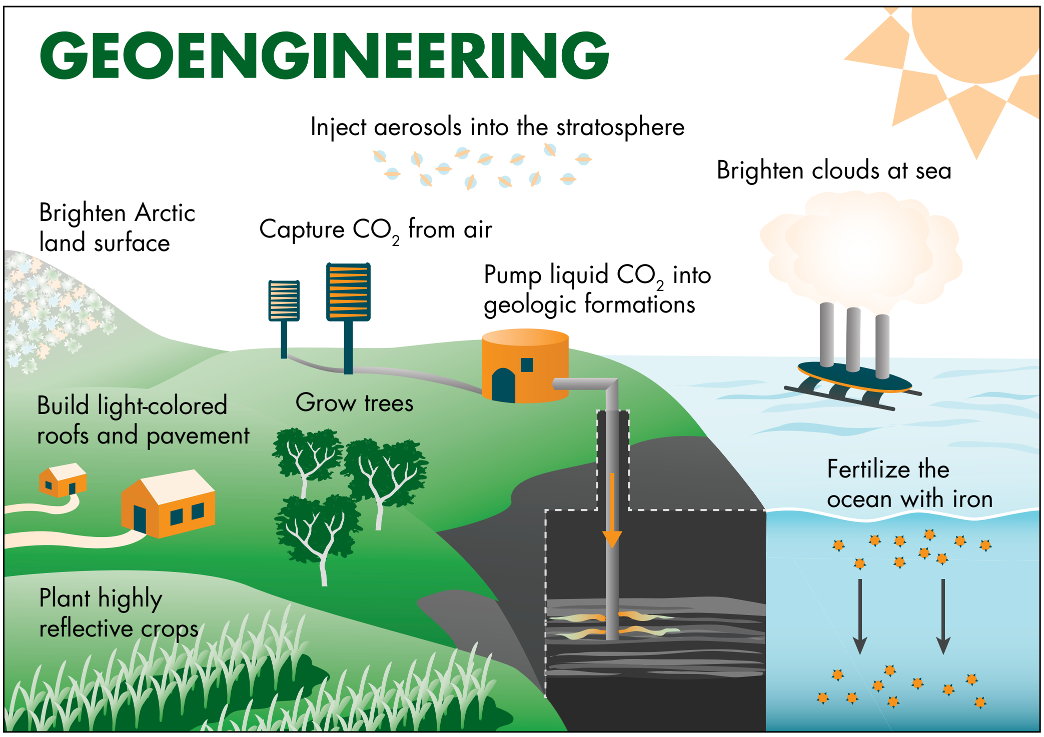
To date, however, geoengineering research efforts have been limited and often not well connected with mainstream climate science programs. This is perhaps caused by funding challenges, significant issues with research governance and openness, and valid



Researchers are discussing many different forms of geoengineering, from injecting aerosols into the atmosphere to block incoming radiation to fertilizing the oceans with iron to instigate large algal blooms that would pull carbon dioxide out of the atmosphere. This diagram shows some of the proposals.

Kathleen Cantner, AGI

concerns that the perceived possibility of a geoengineering "solution" could discourage efforts to mitigate the overarching problem: emissions from fossil-fuel consumption.

Nevertheless, we may ultimately find ourselves in a situation that requires the use of every available tool — mitigation and carbon dioxide removal and solar radiation management — to manage a climate emergency. This motivates a research program that cautiously and rigorously characterizes the efficacy and risks associated with full-scale geoengineering and subscale field tests. Even if geoengineering is ultimately not deployed, an appropriately scoped and coordinated research program could offer co-benefits such as improved climate projections, given that many of the uncertainties associated with geoengineering approaches are the same as those involved in climate modeling.

Instituting a Geoengineering Research Program

What would constitute an appropriate geoengineering research program? Four things come to mind.

First, as highlighted by a recent report by the Bipartisan Policy Center, a nonprofit think tank in Washington, D.C., the issue of governance must be addressed up front to establish guidelines and mechanisms to ensure that geoengineering research is treated with the utmost diligence, scientific integrity and transparency due any such endeavor with profound implications on the national and global public good. Geoengineering research should be open, peer-reviewed and publicly funded — particularly for any proposed efforts to manipulate Earth's atmosphere, oceans or biosphere through field tests.

Second, the research should be guided by well-posed questions derived not just from studies of earth system processes but from potential scenarios for actual deployment of geoengineering schemes. For example, unilateral attempts at regional geoengineering to address a particular climate impact, such as drought, for a given country, may involve different issues than those associated with traditional scenarios that seek to adjust the global thermostat. Likewise, multilateral efforts to avoid or delay a perceived tipping-point event — such as the rapid release of methane from thawing Arctic permafrost — could also drive geoengineering efforts in unique directions.

Third, the research should be truly interdisciplinary in nature, including contributions from the natural sciences, the social sciences and engineering. Solar radiation management research, for example, has historically involved separate efforts to model the climate and to develop component technologies, such as aerosol delivery systems. This piecemeal approach lacks comprehensive systems engineering, in which analysis and inputs from many disparate disciplines are used to evaluate the robustness and manage the risk of the integrated system, including the coupling of individual technologies, actors and the surrounding environment.

The interdisciplinary imperative is underscored by humanity's experience with other complex technologies such as satellites, airplanes, nuclear power stations and deep-ocean drilling where failures to adequately address the many interactions among different components of human and natural systems inevitably lead to bad outcomes. We need to put the engineering into geoengineering — including structured systems analysis and risk assessment that benefit from scientific, technical, sociopolitical, economic and legal perspectives.

Fourth, any geoengineering research program should be well connected with a broader climate science program, not an isolated endeavor. Geoengineering should contribute to the broader strategy for climate change — albeit in most cases as a contingency rather than a primary response option. Research relevant to mitigation and adaptation should continue to receive top priority, with appropriately balanced new investments to add a geoengineering component. This connectivity is particularly important for the process models that underpin geoengineering and general climate studies. These models are essentially the "wind tunnels" for geoengineering and, as with new airplanes, one shouldn't expect people to trust technology that hasn't been first vetted and reviewed by the broader community.

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Options for Study

The W.M. Keck Institute for Space Studies (KISS) at Caltech recently completed a pilot study to identify specific aspects of solar radiation management geoengineering schemes that may warrant prioritization. The study involved preliminary analysis as well as two workshops involving climate researchers both with and without geoengineering expertise. The study emphasized the need for improved understanding of processes to inform risk assessments through the study of natural and human analogs of geoengineering rather than for field experiments or new technology development efforts.

The KISS study identified three topical areas that merit additional attention. First, scientists need a rapid response plan and resources to monitor the aerosols emitted by future large volcanic eruptions, which serve as the best natural analog for one form of solar radiation management. In the past, such eruptions have lofted immense quantities of sulfate particles into the stratosphere, causing significant impacts on incoming solar radiation and global temperatures. But traditionally very few measurement systems have been available to observe the critical processes that occur in the initial months of such eruptions.

Second, assessments of the efficacy of marine cloud seeding on albedo could benefit from a more systematic study of ship-tracks and other aerosol

Mount Pinatubo in the Philippines ejected sulfate aerosols into the stratosphere in 1991. Scientists can use observations of how aerosols move in the stratosphere and how they affect incoming solar radiation to inform possible geoengineering schemes.

U.S. Geological Survey/Richard P. Hoblitt

sources such as coastal smelters that serve as anthropogenic analogs for this geoengineering option. In particular, there could be a large payoff from focused analysis of existing data from multiple satellite sensors and potentially improved satellite and airborne sensors to study the connection among aerosols, clouds and albedo.

Third, there is a need for careful study of targeted intervention scenarios, such as addressing climate tipping-point events or regional climate impacts, to help inform geoengineering research with well-posed questions. Such studies should begin with an assessment of impacts that might prompt geoengineering efforts involving relatively unexplored physical processes.

More expansive efforts following the example of the KISS pilot study are needed. To date, a few small and uncoordinated geoengineering projects have been sponsored by individual governments (including the United States, the United Kingdom and China) and nongovernmental organizations — with no clear connection among them or to broader climate science programs. Geoengineering research merits a well-coordinated effort by the international research community with the highest levels of scientific integrity and transparency. Such a program, if implemented with appropriate resources and governance and guided by well-posed questions, would go a long way to quantifying the risks, efficacy and potential co-benefits of geoengineering.

Furthermore, such a program, if coordinated with the broader climate change science program, could lead to a more comprehensive climate strategy, including a balanced portfolio of primary mitigation and adaptation actions and contingency geoengineering responses. Absent such a program, ad hoc efforts to develop and field test geoengineering methods are likely to continue with varying degrees of scientific rigor, transparency and risk.

Geoengineering is a troubling option that will hopefully never have to be exercised. But the potential need to deploy it rapidly in response to a climate emergency is non-negligible and perhaps growing. Without a better understanding of the relative risks of geoengineering action versus inaction, we could find ourselves in the coming decades grappling with very difficult decisions in an information vacuum. Thus, a balanced geoengineering research program is both prudent and necessary.

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