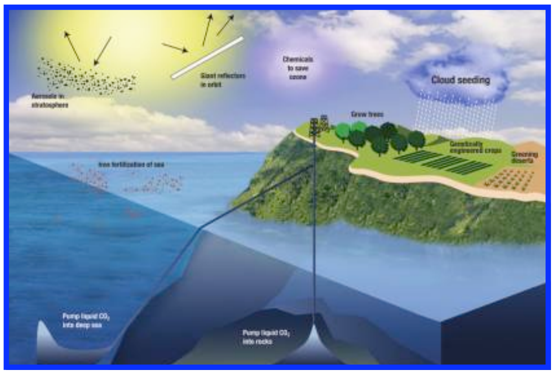
Potential of geoengineering highly uncertain

Despite having the knowledge and tools to dial back greenhouse gas emissions from fossil fuel burning and land-use change, humanity seems on track to continue with business as usual, concludes *Geoengineering the climate: Science, governance and uncertainty*, a report from the U.K.'s Royal Society. The report emphasizes that emissions reductions remain the first priority for mitigating global warming, but geoengineering could play a role as a tool of last resort in the face of a future climate crisis. And so, we'd better learn something about it.

Released on September 1, 2009, the report notes that greenhouse gas emissions are rising by 3% per year. At this rate, the report continues, global mean temperature would increase by 4 C by 2100, a sure recipe for ecosystem catastrophes such as drought, rising sea levels, and melting of the polar ice caps. Concerns over lack of progress have led to a widening discussion in scientific circles about geoengineering—deliberate large-scale intervention in Earth's climate system to moderate global warming.

Geoengineering was once a taboo topic because of fears that the public might wrongly believe that this approach could substitute for actions to cut greenhouse gas emissions. But these days, manipulation of the planet's climate system is garnering high-level attention. The Royal Society report caps a summer in which the American Meteorological Society issued a statement endorsing research on geoengineering and Novim, a nonprofit educational organization, and the Institution of Mechanical Engineers issued their own geoengineering reports.

"The Royal Society report is the first report from a scientific academy wholly devoted to geoengineering, which should help make the topic mainstream," says David Keith, a physicist at the University of Calgary (Canada) and a coauthor of the study. "If you want to be able to manage an unexpectedly dangerous climate response 30 years from now, it's foolish to delay research until you've got a climate emergency—we need to start research now."



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Geoengineering could cool the planet either by sucking CO_2 out of the air or by boosting the reflectance of the earth.

The report describes two ways of modifying Earth's energy balance. One involves sucking CO_2 out of the air and sequestering it by using techniques such as chemical absorption, enhanced weathering of rocks, and fertilizing the oceans to boost planktonic uptake of CO_2. These CO_2 removal methods would allow outgoing long-wave heat radiation to escape more easily, thus cooling the planet. Because the climate system has so much inertia, it would take a long time for CO_2 removal to generate observable impacts. But most of the techniques, with the exception of ocean fertilization, carry a relatively low risk of triggering unintended consequences, according to the report.

The second class of geoengineering proposals, known as solar radiation management, has inherently higher risk. Schemes include pumping sulfate aerosols into the stratosphere and swathing deserts with reflective covers to deflect sunlight, thus reducing the net incoming shortwave solar radiation that heats the planet. Estimates suggest that these techniques could yield temperature changes in a matter of months.

Sulfate aerosols shot into the stratosphere would scatter incoming solar photons, reducing the amount of shortwave radiation reaching the planet, explains Mike MacCracken, an atmospheric scientist with the Climate Institute, a nonprofit organization.

Some models show that reducing solar irradiance by 1–2% could compensate for the global warming effect of a doubling of CO_2 in the atmosphere. This cooling could be achieved by injecting roughly 1.5–5 megatons of sulfur per year into the stratosphere at an annual cost of $8–30 billion, according to the Novim report. Cooling could take place in less than one year.

But significant risks accompany solar radiation management. For example, Simone Tilmes, an atmospheric scientist at the National Center for Atmospheric Research, has used observations from the past to estimate that sulfate aerosols from geoengineering might increase stratospheric ozone depletion at the poles by 30%, delaying recovery of the Antarctic ozone layer by up to 70 years.

"Recent simulations show that doubling the atmospheric CO_2 concentration and also reducing incoming solar energy by 2% would result in very little net change to the global temperature, but would reduce global precipitation by 1.7%," says Phil Duffy, a physicist at Climate Central, a nonprofit educational organization. Rainfall declines would be unevenly distributed, potentially

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triggering drought in some areas, he adds.

Despite the potential for mitigating global warming, solar radiation management does not remove CO_2 from the atmosphere and therefore does not address ocean acidification, which is stressing coral reefs and plankton at the base of the food chain, says Rob Jackson, an environmental scientist at Duke University. The complexity and nonlinear nature of ecosystems make it likely that uncertainty and risk about the impacts of implementing solar radiation management will remain, even after conducting research, he adds.

Many scientists insist that geoengineering must be beneficial and not have harmful effects on its own, MacCracken says. "If that is going to be your criterion, then you would certainly never do geoengineering because at least some nations would very likely experience some adverse impacts," he explains. But, he argues, the question we really face is: what is the relative risk of not doing geoengineering while continuing to emit greenhouse gases compared to the risk of doing geoengineering to offset some of the changes caused by the increasing greenhouse gas concentrations? Global warming seems much more likely to surpass critical thresholds than geoengineering, MacCracken says.

MacCracken suggests that solar radiation management should start on a regional scale. For example, sunlight-deflecting aerosols might be pumped into the Arctic troposphere during the sunlit months to induce cooling that would help to protect critical features, such as the Greenland and Antarctic ice sheets.

But others are more cautious. Research has shown that the aerosols injected into the stratosphere at high latitudes would eventually make their way down to mid-latitudes, slowing the Asian monsoons, says Alan Robock, a climatologist at Rutgers University. The uneven downstream impacts of solar radiation management would mean that some regions would gain from restored climate while others would lose out, potentially leading to geopolitical conflicts, he notes.

"Even if we could do solar radiation management, we'd be out of our minds to try," says Stephen Schneider, a climate scientist at Stanford University. Climate change due to increases in CO_2 is largely irreversible for 1000 years after emissions stop, according to new research by Susan Solomon, a senior scientist at the National Oceanic and Atmospheric Administration. That means that geoengineering aerosols would have to be injected into the stratosphere for a millennium, Schneider says. "It doesn't pass the laugh test to believe that we could come up with a social structure to reliably optimize the collective beliefs of the world's governments as to what an optimal climate would be for 1000 years," he concludes.

"Issues of governance and geopolitical uncertainties are more likely to scuttle geoengineering than the scientific uncertainties," Jackson says. The trickiest issue: who gets to control the climate and for how long? What happens if a country takes matters into its own hands and acts unilaterally? What if another nation experiences drought followed by crop failure—will there be insurance in place to compensate that country? Jackson asks.

"New technologies need new institutions, and we should examine this in advance," says Scott Barrett, an economist at Columbia University. About 12–20 countries are capable of implementing geoengineering today, and because so many have the ability, all would be vulnerable if one of them acted unilaterally. Therefore, these nations are likely to be willing to enter into an agreement for mutual restraint, much like the nuclear test ban treaties, Barrett says.

Critics who are not in favor of global-scale geoengineering, such as Jackson and Schneider, nevertheless say they are in favor of research. "If we choose not to do research, that's a very dangerous thing, because people may implicitly assume that it might work. And then we may find that it won't," Keith warns.

The Royal Society report recommends $17 million per year over 10 years for a U.K. research program on geoengineering. Various small projects are now being funded in the U.S. and Europe on an ad hoc basis, Robock says.

"The longer we wait to cut greenhouse gas emissions, the more likely it is that we'll need geoengineering," Jackson says. In the long run, it is economically more efficient to mount an aggressive program now to cut fossil fuel emissions and invest in alternative energy sources, he concludes.

—JANET PELLEY