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# Opinion | Can Geoegineering Fix Climate Change?

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Guest Essay

## What's the Least Bad Way to Cool the Planet?

The energy infrastructure that powers our civilization must be rebuilt, replacing fossil fuels with carbon-free sources such as solar or nuclear. But even then, zeroing out emissions will not cool the planet. This is a direct consequence of the single most important fact about climate change: Warming is proportional to the cumulative emissions over the industrial era.

Eliminating emissions by about 2050 is a difficult but achievable goal. Suppose it is met. Average temperatures will stop increasing when emissions stop, but cooling will take thousands of years as greenhouse gases slowly dissipate from the atmosphere. Because the world will be a lot hotter by the time emissions reach zero, heat waves and storms will be worse than they are today. And while the heat will stop getting worse, sea level will continue to rise for centuries as polar ice melts in a warmer world. This July was the hottest month ever recorded, but it is likely to be one of the coolest Julys for centuries after emissions reach zero.

Stopping emissions stops making the climate worse. But repairing the damage, insofar as repair is possible, will require more than emissions cuts.

To cool the planet in this century, humans must either remove carbon from the air or use solar geoengineering, a temporary measure that may reduce peak temperatures, extreme storms and other climatic changes. Humans might make the planet Earth more reflective by adding tiny sulfuric acid droplets to the stratosphere from aircraft, whitening low-level clouds over the ocean by spraying sea salt into the air or by other interventions.

Yes, this is what it comes down to: carbon removal or solar geoengineering or both. At least one of them is required to cool the planet this century. There are no other options.

Carbon removal would no doubt trounce geoengineering in a straw poll of climate experts. Removal is riding a wave of support among centrist environmental groups, governments and industry. Solar geoengineering is seen as such a desperate gamble that it was dropped from the important "summary for policymakers" in the United Nations' latest climate report.

Yet if I were asked which method could cut midcentury temperatures with the least environmental risk, I would say geoengineering.

Lest you dismiss me, I founded Carbon Engineering, one of the most visible companies developing technology to capture carbon directly from the air and then pump it underground or use it to make products that contain carbon dioxide. The company's interests could be hurt if geoengineering were seen as an acceptable option. I was also an early proponent for burning biofuels like wood waste, capturing the resulting carbon at the smokestack and storing it underground. I am proud to be a part of the community developing carbon removal. These approaches can help manage hard-to-abate emissions, and they are the only way to reduce the long-term climate risks that will remain when net emissions reach zero.

But the problem with these carbon removal technologies is that they are inherently slow because the carbon that has accumulated in the atmosphere since the Industrial Revolution must be removed ton by ton. Still, the technology provides a long-term cure.

Geoengineering, on the other hand, is cheap and acts fast, but it cannot deflate the carbon bubble. It is a Band-Aid, not a cure.

The trade-off between geoengineering and carbon removal depends on one's time horizon. The sooner cooling is pursued, the greater the environmental and social impacts of carbon removal.

Suppose emissions were under control and you wanted to cool the planet an additional degree by midcentury. How would removal and geoengineering compare?

Carbon removal could work. But it will require an enormous industry. Trees are touted as a natural climate solution, and there are some opportunities to protect natural systems while capturing carbon by allowing deforested landscapes to regrow and pull in carbon dioxide as they do. But cooling this fast cannot be achieved by letting nature run free. Ecosystems would need to be manipulated using irrigation, fire suppression or genetically modified plants whose roots are resistant to rot. This helps to increase the buildup of carbon in soils. To cool a degree by midcentury, this ecological engineering would need to happen at a scale comparable to that of global agriculture or forestry, causing profound disruption of natural ecosystems and the too-often-marginalized people who depend on them.

Industrial removal methods have a much smaller land footprint; a single carbon capture facility occupying a square mile of land could remove a million tons of carbon from the air a year. But building and running this equipment would require energy, steel and cement from a global supply chain. And removing the few hundred billion tons required to cool a degree by midcentury requires a supply chain that might be smaller than what feeds the construction industry but larger than what supports the global mining industry.

The challenge is that a carbon removal operation — industrial or biological — achieves nothing the day it starts, but only cumulatively, year upon year. So, the faster one seeks that one degree of cooling, the faster one must build the removal industry, and the higher the social costs and environmental impacts per degree of cooling.

Geoengineering could also work. The physical scale of intervention is — in some respects — small. Less than two million tons of sulfur per year injected into the stratosphere from a fleet of

about a hundred high-flying aircraft would reflect away sunlight and cool the planet by a degree. The sulfur falls out of the stratosphere in about two years, so cooling is inherently short term and could be adjusted based on political decisions about risk and benefit.

Adding two million tons of sulfur to the atmosphere sounds reckless, yet this is only about one-twentieth of the annual sulfur pollution from today's fossil fuels. Geoengineering might worsen air pollution or damage the global ozone layer, and it will certainly exacerbate some climate changes, making some regions wetter or drier even as it cools the world. While limited, the science so far suggests that the harms that would result from shaving a degree off global temperatures would be small compared with the benefits. Air pollution deaths from the added sulfur in the air would be more than offset by declines in the number of deaths from extreme heat, which would be 10 to 100 times larger.

Geoengineering's grand challenge is geopolitical: Which country or countries get to decide to inject aerosols into the atmosphere, on what scale and for how long? There is no easy path to a stable and legitimate governance process for a cheap, high-leverage technology in an unstable world.

Which is better? Carbon removal is doubtless the safest path to permanent cooling, but solar geoengineering may well be able to cool the world this century with fewer environmental impacts and less social and economic disruption. Yet no one knows, because the question is not being asked. Geoengineering research budgets are minuscule, and much of the work is accomplished after hours by scientists acting outside their institutions' priorities.

The United Nations Intergovernmental Panel on Climate Change assumes enormous use of carbon removal to meet the Paris Agreement target of 1.5 degrees Celsius (2.7 degrees Fahrenheit), but not because scientists carefully compared removal and geoengineering. This was a glaring omission in the I.P.C.C. report, given that one of the very few areas of agreement about geoengineering is that it could lower global temperatures.

Research is minimal because geoengineering has influential opponents. The strongest opposition to geoengineering research stems from fear that the technology will be exploited by the powerful to maintain the status quo. Why cut emissions if we can seed the atmosphere with sulfur and keep the planet cool? This is geoengineering's moral hazard.

This threat is real, but I don't find it a convincing basis to forgo research, particularly given evidence that support for geoengineering research is stronger in regions that are poorer and more vulnerable to climate change, regions that would benefit most from cooling.

Some will no doubt exaggerate the benefits of solar geoengineering to protect the fossil fuel industry. But this threat is not unique to geoengineering. Carbon removal may pose a stronger moral hazard today. Activists like Al Gore once opposed adaptive measures such as flood protection, out of fear it would distract from emission cuts. They now embrace such measures, yet support for emissions cuts has never been higher, proving that support for one method of limiting climate risks need not reduce support for others.

Emissions cuts are necessary. But pretending that climate change can be solved with emissions cuts alone is a dangerous fantasy. If you want to reduce risks from the emissions already in the atmosphere — whether that's to prevent forest fires in Algeria, heat waves in British Columbia or floods in Germany — you must look to carbon removal, solar geoengineering and local adaptation.

Emissions monomania is not an ethical climate policy because those three approaches together do what emissions cuts cannot: They reduce the future harms caused by historical emissions and provide a reason to hope that collective action can begin repairing Earth's climate within a human lifetime.

Perhaps the best reason to take cooling seriously is that benefits seem likely to go to the poorest countries. Heat reduces intellectual and physical productivity with economywide consequences. Hotter regions are more sensitive to extra degrees of warming, while some cool regions may even benefit. A year that's a degree warmer than normal will see economic growth in India reduced by about 17 percent, while Sweden will see growth increased by about 22 percent.

Poor people tend to live in hot places. This, combined with the fact that an added degree causes more harm in warmer climates, explains why the costs of climate change fall heaviest on the poor — and why the benefits of cooling will be felt the most in the hottest regions.

This dynamic explains why the one study to quantitatively examine the consequences of geoengineering for global inequality found that it might reduce economic inequality by about 25 percent, similar to the impressive reduction the United States achieved in the four decades following the New Deal.

Cooling the planet to reduce human suffering in this century will require carbon removal or solar geoengineering or both. The trade-offs between them are uncertain because little comparative research has been done. The fact that one or both are taboo in some green circles is a dreadful misstep of contemporary environmentalism. Climate justice demands fast action to cut emissions *and* serious exploration of pathways to a cooler future.

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