

PAS QUICKNOTES

Geoengineering

The rapidly accelerating impacts of climate change have triggered increased interest in **geoengineering**: the intentional, large-scale manipulation of natural systems to mitigate global warming. Because geoengineering approaches tend to have worldwide consequences, this topic is subject to much international debate. Planners should be aware of the potential benefits and repercussions of geoengineering and the ways in which its implementation may have implications for their work.

BACKGROUND

The most recent annual **Emissions Gap report** from the United Nations found that nearly 3°C of global warming would be likely by 2100 given countries' current climate pledges, far exceeding the 1.5°C threshold set in the **Paris Agreement** and increasing the likelihood of severe climate impacts in the years to come. The world is already feeling the impacts of a warming climate: in 2023 there were **28 billion-dollar disasters** in the United States alone, amounting to over \$93 billion in damages.

The failure of current efforts worldwide to curtail greenhouse gas (GHG) emissions has many scientists, engineers, politicians, and others seriously considering geoengineering tactics to mitigate global warming. Analysis already suggests that removing carbon dioxide from the atmosphere will be necessary to meet the goals of the Paris Agreement. There is debate, however, over which geoengineering approaches will and should ultimately be deployed, with carbon dioxide removal already a reality and weather modification and solar radiation management both garnering increased attention and scrutiny.

CARBON DIOXIDE REMOVAL

Carbon dioxide removal (CDR) comprises any method that takes carbon dioxide out of the atmosphere, resulting in negative emissions. At present, this is the most common form of geoengineering, with **nearly 800** completed, ongoing, or planned projects. There are many ways to achieve CDR with varying degrees of required technology and ease of implementation. **Strategies** include the following:

- **Afforestation**: planting trees in areas that previously did not have tree cover to absorb and store carbon as they grow (a related strategy is reforestation, planting trees to replace previously existing forests that have been cut down).
- **Soil-based carbon sequestration**: implementation of one or more methods that increase the amount of carbon stored in soil, including the planting of perennial and cover crops, using low- or no-till farming practices, and improving livestock grazing management.
- **Direct air capture (DAC)**: the process of removing carbon dioxide from the air and either storing it or using it in industries such as agriculture and synthetic fuels. DAC differs from **carbon capture** in that it can be executed anywhere, while carbon capture targets point-source emissions.

One recent milestone for CDR implementation came in November 2023, when the **first DAC plant** began operating in the United States. Ongoing **DAC funding** from the 2023 Bipartisan Infrastructure Law will expand the scope of this technology. Projects such as these may require zoning changes to accommodate the infrastructure and use cases required. Moreover, planners can help integrate **more passive forms of CDR** through afforestation and the creation and expansion of green spaces, and they can also support regenerative farmland preservation through more sustainable food systems planning.

WEATHER MODIFICATION

Weather modification consists of any intentional intervention to produce artificial changes in atmospheric behavior. It is far less prevalent than CDR, with **around 65** ongoing or planned projects. Strategies to induce changes in weather include the following:

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Geoengineering strategies to combat climate change include modifying the atmosphere to reduce the amount of sunlight reaching the Earth. Credit: modestbike/iStock



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- **Cloud seeding:** the distribution of substances into clouds or fog to change how they would otherwise develop and behave.
- **Atmospheric ionization:** the injection of ions into the atmosphere to produce more cloud cover or rainfall.
- **Laser-based weather control:** using ultrashort laser pulses to trigger the formation of clouds by inducing condensation.

Cloud seeding has been in effect in some places for decades. Several Western U.S. states use it to combat drought; **Utah**, which has been employing cloud seeding since the 1950s, currently dedicates a \$5 million annual budget to its execution.

Planners should be aware of how changing weather patterns may affect broader design considerations for the built environment. For instance, cloud seeding in arid regions can potentially support green space creation and afforestation in areas where these approaches were not previously viable.

SOLAR RADIATION MANAGEMENT

Solar radiation management or modification (SRM) encapsulates a series of strategies that reflect sunlight away from Earth to reduce the amount that reaches the surface. SRM is the most contentious of geoengineering approaches; there are currently **fewer than 20** ongoing projects. **Strategies** to reflect sunlight include the following:

- **Surface or ocean albedo modification:** changing the surface of the planet to reflect more sunlight away from Earth; this includes ideas such as clear-cutting boreal forests in snowy climates and micro-bubbling of water bodies.
- **Marine cloud brightening:** the injection of substances such as **seawater aerosols** or sulfur dioxide into clouds that form over the ocean to increase their reflectivity.
- **Stratospheric aerosol injection:** the injection of **aerosols into the stratosphere** by high-altitude planes or balloons to reflect sunlight and prevent it from reaching Earth.
- **Space-based techniques:** strategies that attempt to reduce the amount of light that reaches Earth's surface by sending objects into space that can reflect the sun's light, such as mirrors and sunshades.

SRM is the subject of much debate in the realm of geoengineering, and **Mexico** has banned SRM experimentation following unauthorized small-scale tests of this approach. Illustrating the complexity of atmospheric systems, recent reductions in the sulfur content of maritime fuels to improve air quality became an **unintended SRM experiment** when researchers discovered that cleaner emissions led to fewer "ship tracks," highly reflective clouds caused by sulfur dioxide emissions from cargo ships. This boosted the amount of sunlight hitting the ocean by 50 percent in Atlantic shipping corridors, accelerating oceanic and planetary warming.

A 2023 UN Environment Program **report** outlines actions the international community should take on SRM, including developing governance frameworks for SRM experiments and deployments and instituting regular scientific reviews of climate change impacts with and without intervention from SRM. Planners should watch for further developments in this field.

CONCLUSIONS

While some forms of geoengineering have been employed for decades, the intensifying need to address global warming is prompting research and experimentation into additional new strategies. The feasibility and risks of many of these approaches, however, are still under debate. As the impacts of climate change worsen, planners must be prepared for the myriad ways in which geoengineering is already beginning to affect their work.

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FURTHER READING

Published by the American Planning Association

Hurtado, Petra, Sagar Shah, Joseph DeAngelis, Ievgeniia Dulko, Senna Cat-enacci, and Scarlet Andrzejczak. 2024. "Mitigating Climate Change Through Geoengineering." Pages 61–62 in *2024 Trend Report for Planners*. Chicago: American Planning Association and Lincoln Institute of Land Policy.

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Other Resources

Geoengineering Monitor. n.d. [Geoengineering Map](#).

Riedl, Danielle, and Katie Lebling. 2023. "4 Things to Know About New Developments in Carbon Dioxide Removal." *World Resources Institute Explainer*, April 10.

Harvard's Solar Geoengineering Research Program. n.d. [Geoengineering](#). Harvard University Center for the Environment.