The merits or otherwise of Geoengineering

Written by James Ware – HOPE researcher Qld

Geoengineering—the deliberate large-scale intervention in Earth's climate system—has gained attention as a potential tool to combat climate change. It encompasses various methods, primarily categorized into Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM).

Below herewith are the specific geoengineering techniques outlined in detail, highlighting the mechanisms, benefits, risks, and recent developments of each.

1. Solar Radiation Management (SRM)

How It Works:

SRM aims to reflect a small fraction of sunlight back into space to cool the planet. Common approaches include:

- **Stratospheric Aerosol Injection (SAI):** Spraying reflective particles (e.g., sulphur dioxide) into the upper atmosphere to mimic volcanic cooling effects.
- **Marine Cloud Brightening:** Increasing the reflectivity of clouds over oceans by spraying sea salt particles.
- **Space-based Reflectors:** Deploying mirrors or reflective materials in orbit to reduce solar radiation reaching Earth.

Benefits:

- Can reduce global temperatures rapidly (within months to years).
- Potentially low cost compared to other climate interventions.
- Provides a temporary "emergency brake" against extreme warming.

Risks and Challenges:

- May disrupt regional rainfall patterns, affecting agriculture and water supply, especially in vulnerable regions like South Asia and Africa.
- Does not reduce greenhouse gases or ocean acidification.
- Risk of "termination shock" if abruptly stopped, causing rapid warming.
- Governance and ethical concerns due to unilateral deployment risks.

Recent Developments:

- Small-scale outdoor experiments are being planned or debated (e.g., SCoPEx by Harvard University).
- Growing calls for international governance frameworks to regulate research and deployment.

2. Carbon Dioxide Removal (CDR)

How It Works:

CDR methods actively remove CO_2 from the atmosphere and store it long-term. Techniques include:

- **Afforestation and Reforestation:** Planting trees to absorb CO_2 through photosynthesis.
- **Bioenergy with Carbon Capture and Storage (BECCS):** Growing biomass for energy and capturing emitted CO_2 underground.
- **Direct Air Capture (DAC):** Using chemical processes to extract CO_2 directly from ambient air.
- **Enhanced Weathering:** Spreading crushed minerals (e.g., olivine) on land or ocean to chemically bind CO_2.
- **Ocean Fertilization:** Adding nutrients to oceans to stimulate phytoplankton growth, which absorbs CO_2.

Benefits:

- Addresses the root cause of climate change by reducing atmospheric CO_2.
- Can help restore ocean chemistry and reduce acidification.
- Many methods (like afforestation) offer co-benefits for biodiversity and soil health.

Risks and Challenges:

- Some methods (e.g., ocean fertilization) have uncertain ecological impacts.
- High energy and cost requirements for technologies like DAC.
- Land and water use competition for large-scale afforestation or BECCS.
- Slow to scale up and realize significant impact compared to SRM.

Recent Developments:

- DAC companies are scaling pilot projects globally, with some commercial plants operational.
- International initiatives (e.g., the Global Carbon Removal Partnership) promote research and deployment.
- IPCC emphasizes CDR as essential for meeting net-zero targets.

3. Ocean-Based Geoengineering

How It Works:

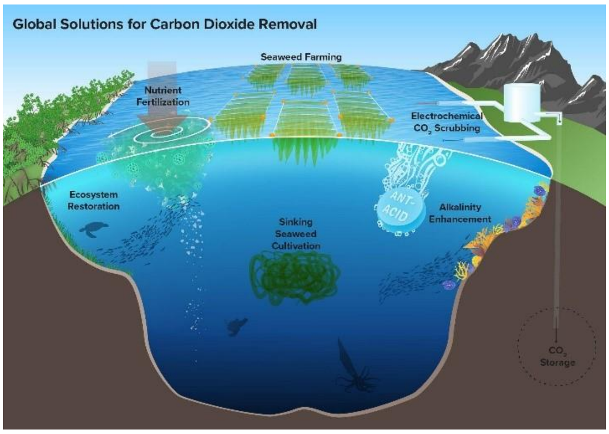
These techniques modify ocean processes to enhance carbon sequestration or reflect sunlight:

- **Ocean Fertilization:** Adding iron or other nutrients to stimulate phytoplankton blooms that absorb CO_2.
- **Ocean Alkalinity Enhancement:** Adding alkaline substances to increase ocean's capacity to absorb CO_2.
- **Seaweed Cultivation:** Growing and harvesting seaweed to sequester carbon and produce biofuels.

Benefits:

- Potentially large carbon sink due to ocean's vast size.
- Can improve marine ecosystems if done carefully.

Risks and Challenges:



- Uncertain ecological impacts, such as harmful algal blooms or oxygen depletion.
- Difficult to monitor and verify carbon sequestration.
- Legal and governance complexities under international maritime law.

Recent Developments:

- Research projects testing small-scale ocean fertilization with mixed results.
- Increasing interest in seaweed farming for both carbon sequestration and sustainable products.

Summary

Technique	Key Benefit	Main Risks	Status & Outlook
Stratospheric Aerosol Injection (SAI)	Rapid temperature reduction	Weather disruption, termination shock	Early research, governance needed
Direct Air Capture (DAC)	Removes CO_2 directly	High cost and energy use	Pilot plants operational, scaling up
Afforestation/Reforestation	Ecosystem co-benefits	Land use competition	Widely practiced, needs scale-up
Ocean Fertilization	Large carbon sink potential	Ecological uncertainty	Experimental, controversial
Marine Cloud Brightening	Rapid cooling potential	Regional climate impacts	Early research, small-scale tests planned

Understanding the merits and drawbacks of geoengineering is crucial for informed decision-making about its role in sustainability and climate resilience.

Merits of Geoengineering

1. **Rapid Climate Cooling Potential (SRM)**
    - Solar Radiation Management techniques, such as injecting aerosols into the stratosphere, can quickly reduce global temperatures by reflecting sunlight away from Earth.
    - This rapid cooling could be critical to avoid extreme climate tipping points in the near term.

2. **Complement to Emission Reductions**
    - Geoengineering is not a replacement but could complement greenhouse gas emission reductions by buying time while transitioning to low-carbon economies.
    - Carbon Dioxide Removal methods (e.g., direct air capture, afforestation) actively reduce atmospheric CO_2, addressing the root cause of warming.

3. **Potential to Reverse Some Climate Impacts**
    - Removing CO_2 can help restore ocean pH and reduce acidification, benefiting marine ecosystems.
    - Cooling effects can reduce heat stress on vulnerable populations and ecosystems.
4. **Technological Innovation and Economic Opportunities**
    - Development of geoengineering technologies could spur innovation, create green jobs, and foster new industries aligned with climate goals.

Concerns about Geoengineering

1. **Environmental Risks and Unknowns**
    - Solar Radiation Management could disrupt regional weather patterns, such as monsoons, potentially causing droughts or floods in vulnerable regions.
2. Ocean fertilization (a form of CDR) may alter marine ecosystems unpredictably.
   Moral Hazard and Governance Challenges
    - Geoengineering might reduce the urgency to cut greenhouse gas emissions, creating a moral hazard.
    - Lack of international governance frameworks raises concerns about unilateral deployment and geopolitical conflicts.
3. **Temporary and Imperfect Solutions**
    - SRM does not address ocean acidification or the root cause of climate change (CO_2 emissions).
    - If SRM is abruptly stopped, a rapid temperature rebound could occur, worsening impacts.

4. **Ethical and Social Concerns**

- Potential impacts on indigenous peoples, developing countries, and future generations raise ethical questions.

- Public acceptance is low due to fears of "playing God" with the climate.

Summary Table

Merit	**Concern**
Rapid cooling to avoid tipping points	Risk of unintended climate disruptions
Removes CO_2 and addresses root cause	Moral hazard reducing emission cuts
Complementary to mitigation efforts	Governance and geopolitical risks
Potential economic and tech benefits	Temporary effect, not a permanent fix
Can protect vulnerable ecosystems	Ethical and social justice issues

Material for this article sourced from:

- National Academies of Sciences, Engineering, and Medicine (2021), *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*
  NAP Report
- IPCC AR6 WG1 (2021), *Climate Change 2021: The Physical Science Basis*
  IPCC Report
- IPCC AR6 WG3 (2022), *Mitigation of Climate Change*
  IPCC Report

- Royal Society (2009), *Geoengineering the Climate: Science, Governance and Uncertainty* Royal Society Report
- National Academy of Sciences (2019), *Negative Emissions Technologies and Reliable Sequestration* - NAS Report
- National Academy of Sciences (2015), *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration* - NAS Report
- Environmental Research Letters (2018), *Ocean Alkalinity Enhancement to Mitigate Climate Change* - ERL Article
- Climate Policy Journal, 2020
- IPCC Special Report on Climate Change and Land, 2019
- Environmental Research Letters, 2018
- The Lancet Planetary Health (2019) — *Ethics and governance of geoengineering* https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(19)30018-4/fulltext