# Quarterly Review #2: Marine Geoengineering

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## Marine Geoengineering: The number of greenhouse gas removal projects in marine environments continues to grow, along with the number of marine research projects and field trials

In recent months, interest in marine geoengineering projects has noticeably increased. New research projects have been launched, new theoretical marine geoengineering technologies have been presented and attempts are being made to commercialize **marine geoengineering.**

Greenhouse Gas Removal (GGR) refers to a set of proposed technologies that remove greenhouse gases from the atmosphere. The interactive world map on geoengineering, a tool generated by ETC Group and the Heinrich Böll Foundation, shows that the number of GGR projects in marine environments is steadily increasing. So far, the share of marine geoengineering projects accounted for about 10 %[1] of all known geoengineering projects. However, when considering only the known planned projects, the share has more than tripled. The number of planned marine research, Carbon Capture and Storage (CCS) and Enhanced Weathering projects in particular have increased. For example, the proportion of CCS projects planning to pump $CO_2$ under the seabed has more than quadrupled.[2] An international team of researchers explains that the growing hype around marine GGR projects is driven in part by the fact that the technical and political challenges of land-based GGR projects are becoming more apparent. Another possible reason cited is the commercial nature of marine GGR projects, which are likely to be hyped to attract capital – citing Project Vesta and the philanthropically funded Ocean CDR knowledge hub as examples.

### Like land-based GGR projects, marine GGR projects consume a lot of resources, pose unmanageable risks to the environment and do

## not address the underlying causes of climate change

A team of researchers at UCLA, the University of California, base their interest in marine GGR on the fact that seawater contains almost 150 times more $CO_2$ compared to ambient air. The researchers propose an approach to remove $CO_2$ from the atmosphere that involves extracting $CO_2$ from seawater. They argue that $CO_2$ capture in ocean water is more efficient than direct air capture due to the significantly higher $CO_2$ concentration; and they expect that due to the removal of $CO_2$, seawater can reabsorb more $CO_2$ from the atmosphere. The process, which has so far only been tested at lab-scale, is called “single-step carbon sequestration and storage (sCS2)” and functions as follows: Sea water is pumped into the sCS2 plant. By adding sodium hydroxide (NaOH) and an electrical charge, the dissolved $CO_2$ reacts with magnesium (Mg) and calcium (Ca) contained in sea water and forms carbon minerals. After dewatering and separating the solid minerals, the water is returned to the ocean and the solids must be disposed of. To capture 10 billion tonnes of $CO_2$ annually, equal to about 30 % of global energy-related $CO_2$ emissions[3], the UCLA team estimated that nearly 1,800 sCS2 plants would be required, at a cost of trillions of dollars. This scenario would result in the following environmental costs and risks:

- **Coastal habitat destruction** due to large-scale development along the coasts.
- **~14 km³ space for waste annually** as the annual removal of 10 billion tonnes of $CO_2$ generates 20 billion tonnes of solids. Whether a small amount of these solids could be used as building material is uncertain.
- **10 times the annual U.S. electricity consumption**[4] as the estimated annual energy consumption for capturing 10 billion tonnes of $CO_2$ is 45 billion MWh for the sCS2 plant and ~1.5 billion MWh for seawater pumping. And this energy consumption estimate is not even exhaustive; among other things, the energy consumed for transporting the solids to the landfill and for producing and handling the required NaOH is missing.
- **~18 billion tonnes of NaOH annually are required:** The production of NaOH is very energy intensive. In addition, NaOH poses environmental risks; according to the European Chemical Agency, it is acutely toxic to aquatic organisms even in low concentrations.
- **Potential negative impacts to marine ecosystems or species** as sCS2 plants remove 9.1 billion tonnes of Ca or 5.5 billion tonnes of Mg from seawater annually.

If implemented at scale, the UCLA research proposal entails environmental risks, natural habitat destruction due to land consumption and a very high demand for energy and chemicals. It is scarcely conceivable that the large amounts of renewable energy required can be generated without automatically further delaying the phase-out of fossil fuels and thereby causing unnecessary further GHG emissions.

## The Centre for Climate Repair at Cambridge University aims to promote and test marine geoengineering technologies associated with risks to the marine food web

The Centre for Climate Repair at Cambridge University (CCRC) plans to pursue a technology proposed by Stephen Salter and John Latham, that aims to create whiter clouds to reflect more sunlight back into space. This theoretical solar geoengineering technique is named Marine Cloud Brightening (MCB) and is expected to work based on condensation nuclei shot into marine clouds. Salter and Latham, both UK-based researchers, modelled the idea of using several hundred wind-powered ships, each at a cost of £ 2.5 million, to shoot saltwater droplets into the sky to brighten marine clouds. The CCRC plans to support design and construction of a prototype and to hire a graduate student to improve, for example, the nozzles for spraying the droplets. Modelling results predict that MCB is likely to have major unintended environmental consequences, such as to weather patterns, including substantial reductions in precipitation in ecologically important rainforest areas.[5]

The CCRC also announced ocean fertilization trials with iron at three sites in the world's oceans within the next four years and has established relationships with the National Institute of Oceanography Goa in India, the U.S. University of Hawaii and Incheon University in South Korea in this regard. All of the aforementioned institutions have previously been involved in marine geoengineering experiments. Exact arrangements regarding the location, scope and timing of the trials are not yet publicly available. Ocean fertilization aims to stimulate biological productivity by dumping large amounts of nutrients such as iron into ocean areas on the assumption that new phytoplankton growth will absorb $CO_2$ and store the carbon as it dies and sinks to the seafloor. There have been at least 16 fertilization experiments in the open ocean over the past three decades, but no effective carbon storage has been demonstrated. In addition, scientists point to possible risks, particularly adverse effects on the marine food web, oxygen depletion, and harmful toxin-producing algal blooms.[6]

The CCRC was launched in 2019 and is part of the University's Cambridge Zero programme, which is co-ordinated by Sir David King, a former chief scientific adviser to the UK government. The CCRC is dedicated to reducing greenhouse gas emissions, removing greenhouse gases from the atmosphere, and restoring disrupted climate systems. The Centre aims to achieve these goals not only with MCB and Ocean Fertilization, but also with geoengineering technologies such as Direct Air Capture (DAC),  Enhanced Freezing. In June 2021, David King founded the Climate Crisis Advisory Group (CCAG). The first CCAG reports repeat the CCRC's Geoengineering approaches and proposals.

Another programme that has recently begun to address marine geoengineering in the UK, is the British Greenhouse Gas Removal Programme. This research programme was launched in 2017 and aims to enhance knowledge of the means to remove greenhouse gases from the atmosphere at a scale relevant to climate change. In 2021, 24 new projects were selected to participate in the programme, including two marine geoengineering projects related to direct $CO_2$ removal from seawater and $CO_2$ removal through ocean alkalinity enhancement. In addition, the topics of direct air capture, BECCS, biochar, enhanced weathering and Carbon Capture Use and Storage (CCUS) are being funded.

## The German Federal Ministry of Education and Research explores marine geoengineering technologies and current hurdles to conducting field studies

The German Federal Ministry of Education and Research (BMBF) has also provided funding for marine geoengineering, supporting two research projects. The project ASMASYS is led by the German Leibniz Institute for Baltic Sea Research, in Warnemünde, and aims to explore whether and by which measures atmospheric $CO_2$ can be removed from marine environments. In addition, the project investigates current barriers for field studies as well as legal, social and ethical aspects for marine GGR. The project Carbon Dioxide Removal by Alkalinity Enhancement: Potential, Benefits and Risks (RETAKE) is led by the GEOMAR Helmholtz Centre for Ocean Research in Kiel and aims at modelling and researching alkalinity enhancement in German waters and various open-ocean regions worldwide. Modelling will be performed on the basis of culture experiments and mesocosms studies. Where and to what extent the studies with mesocosms, which can be described as very large test tubes, will be conducted in the open ocean is not yet publicly disclosed.

## Numerous new studies on marine geoengineering

A particularly large number of research papers on marine geoengineering were published in the past quarter; here is a selection:

- Italian and British researchers investigated the possibility of discharging calcium hydroxide through existing maritime traffic, aiming to increase the alkalinity of the oceans;
- Chinese researchers investigated whether it is possible to improve $CO_2$ storage through ocean fertilization with iron by adding not only iron but also further substances to marine waters;
- Australian researchers investigated the possibility of counteracting the acidification of the Great Barrier Reef with Ocean Alkalinity Enhancement. The researchers concluded that the approach is "*likely to be extremely expensive, include as yet unquantified risks*";
- A team of researchers from the United States investigated how long $CO_2$ remains in the ocean after injection and how this retention time can be extended.

## Plans for commercial marine geoengineering projects would encroach on delicate coastal and glacial environments

The Arctic Ice Project was founded in 2007, is headquartered in California and suggests covering Arctic ice with a layer of floating reflective material to slow down the melting of the ice or to restore ice. The proposed cover material is a reflective silica glass, consists mostly of silicon dioxide and has the form of tiny hollow glass spheres. The project's initial plan is covering a large area of selected arctic regions, e.g., Fram Strait or Beaufort Gyre, with reflective material to prevent strategic areas of ice from melting, aiming to block larger ice sheets in the Arctic Ocean from floating south, where they would melt faster. However, the project is now proposing the same concept for larger land ice areas – glacier areas in the Himalayas, Greenland and Alberta, are also being considered as possible target areas. The proposal would result in millions of tiny glass spheres being released into the environment. The potential negative impacts of this proposal, such as changing weather patterns or impacts on delicate ecosystems, as well as the environmental impact of the cover material itself, have not yet been thoroughly investigated. Estimates for covering 50,000 $km^2$ with silica glass indicated material costs of around US$ 750 million.[7]

In 2020, Project Vesta announced plans to trial enhanced weathering with olivine – a soft, green, volcanic stone – at an experimental site. The site consists of two coves that are a quarter mile apart: one cove would be a test area where mined and ground olivine pebbles would be applied and the other nearby cove would be a control area. The exact location of the trial site is still unknown, but it is likely to be a stretch of coastline in the Dominican Republic. The planned enhanced weathering trial aims to mimic the natural weathering processes of silicate and carbonate rocks that sequester larger amounts of $CO_2$ from the atmosphere each year. The acceleration of the weathering process would theoretically be achieved by mining and crushing large amounts of suitable rocks, such as olivine, and by wave action. As it takes about two tonnes of rocks to absorb one tonne of $CO_2$, this means quarrying large amounts of rock, which is, among other things, very costly and energy-intensive, generates large amounts of greenhouse gases and can trigger unintended biogeochemical processes in coastal and marine environments.

None of the proposed marine geoengineering technologies have proven successful so far – although some of them have been researched for decades. The potential risks alone speak against their use as well as further research. Apart from that, many of the proposals consume large amounts of resources and energy. If energy-intensive approaches were to be used on a large scale, this could make it more difficult to phase out fossil fuels.

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[1] ETC Group and Heinrich Böll Foundation, "Geoengineering Map" (July 2021), https://map.geoengineeringmonitor.org/. As of July 2021: Among the known ongoing and completed projects, schemes with reference to marine geoengineering accounted for about 10 %.

[2] ETC Group and Heinrich Böll Foundation, "Geoengineering Map" (July 2021), https://map.geoengineeringmonitor.org/. As of July 2021: Of the completed CCS projects, 6 % aimed to pump $CO_2$ under the seabed. For planned projects, the share has risen to 27 %. 10 % of the completed research projects have dealt with marine geoengineering. The share among the planned research projects known to date is 50 %. 20 % of completed Enhanced Weathering projects were related to the marine environment; this has increased to 80 % for planned projects.

[3] International Energy Agency, "$CO_2$ emissions" (July 2021), https://www.iea.org/reports/global-energy-review-2021/co2-emissions: "*Despite the decline in 2020, global energy-related $CO_2$ emissions remained at 31.5 Gt*"

[4] 13.1 MWh electricity consumption per Capita in the USA according to the International Energy Agency (accessed: July 2021). ~330,000,000 inhabitants according to the United Status Census Bureau (accessed: July 2021).

[5] ETC Group and Heinrich Böll Foundation (July 2021) "Geoengineering Map", https://map.geoengineeringmonitor.org/; PhD studentship supported by the Centre for Climate Repair at Cambridge (accessed: July 2021) https://www.postgraduate.study.cam.ac.uk/courses/studentships/nm26696; ETC Group and Heinrich Böll Foundation (January 2021), "Geoengineering Technology Briefing: Marine Cloud Brightening or Cloud Reflectivity Enhancement", https://www.geoengineeringmonitor.org/wp-content/uploads/2021/04/marine-cloud-brightening.pdf

[6] ETC Group and Heinrich Böll Foundation (July 2021) "Geoengineering Map", https://map.geoengineeringmonitor.org/; ETC Group and Heinrich Böll Foundation (January 2021) "Geoengineering Technology Briefing: Ocean Fertilization", https://www.geoengineeringmonitor.org/wp-content/uploads/2021/04/ocean-fertilization.pdf

[7] ETC Group and Heinrich Böll Foundation (July 2021) "Geoengineering Map", https://map.geoengineeringmonitor.org/; ETC Group and Heinrich Böll Foundation (January 2021) "Geoengineering Technology Briefing: Surface Albedo Modification", https://www.geoengineeringmonitor.org/wp-content/uploads/2021/04/surface-albedo-modification.pdf