Commercialization in geoengineering continues to increase

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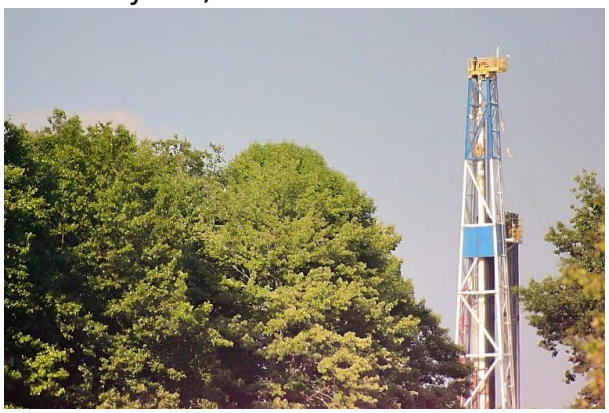

By Anja Chalmin

The Quarterly Review summarises the latest developments on the Geoengineering Monitor Map highlighting emerging trends for civil society and climate justice movements.

Key Points – Quarterly Review IV

- In the last quarter of 2022, the trend continues that more and more companies and organisations that have developed and want to commercialise geoengineering technologies intend to test them on land, water and in the air. Details of the tests are often not accessible to the public. This also applies to publicly funded trials.
- Most geoengineering approaches are still about capturing CO2 from exhaust gases, ambient air and water bodies, and then processing the captured CO2 into consumer products or injecting it underground. But there are also new attempts to manipulate the Earth's reflectivity and use the deep sea as a CO2 storage site.
- Many geoengineering projects aim to finance themselves through CO2 certificates and to generate revenue from CO2 certificates.
- Outdoor experiments tend to be conceptualised in North America or Europe, but are conducted in the southern hemisphere. A prime example is the UK's The Degrees Initiative, which is now funding 26 solar radiation management modelling projects in the Global South.

SEAWEED AND BIOMASS SINKING FOR CARBON SEQUESTRATION

Wide-ranging concerns about deep-sea dumping of seaweed/biomass

There is growing interest in using the Deep Sea as a CO2 storage site. Not only as a storage site for captured CO2 to be injected into depleted oil and gas fields. There are a growing number of projects aimed at producing marine and terrestrial biomass for subsequent dumping into the deep sea. Blue carbon credits are then to be marketed on this basis.

However, these projects/ambitions/techniques come with great uncertainties about the risks for marine ecosystems/environment and about the climate effectiveness of the techniques.

The European Commission's Blue Bioeconomy Report, published in January 2023, takes the following positions:

- *"Seaweed sinking for carbon sequestration purposes so far has no proof of positive environmental, climate*

or economic benefits. Hence, in the present state of knowledge, it should not be considered as a valid policy option." (p. 104 of the Blue Bioeconomy Report)
- *"Science is not robust enough for blue carbon credits to be extended to seaweed ecosystems and seaweed farming."*

Concerns raised in the report include the grazing and re-mineralisation of seagrass before it reaches the deep sea, the logistical complications of, for example, bundling seagrass, uncontrolled dispersal and the fact that too little is known about deep-sea ecosystems to predict the ecological consequences of such an input.

A recent statement by the Parties to the London Protocol / London Convention (LP/LC) on marine geoengineering noted a"need to carefully evaluate marine geoengineering techniques", because they "may have adverse impacts on the marine environment". The Parties identified techniques for priority evaluation: enhanced ocean alkalinity (marine enhanced weathering), macroalgae cultivation and other biomass for sequestration including artificial upwelling, marine cloud brightening, microbubbles, and reflective particles/material.

Deep-sea seaweed/biomass disposal: recent plans for open-sea testing and commercialisation

Seafields Solutions Ltd. – Mexico, St. Vincent, Cape Verde, Ascension Island, South Atlantic
The UK-based company Seafields aims to cultivate the fast-growing and invasive marine seaweed Sargassum in the open sea and use artificial upwelling to supply the seaweed with nutrients. The harvested seaweed is to be pressed into bales and sunk into the deep sea. The 'captured' CO2 will be marketed as carbon credits. Since 2021, Seafields has been testing Sargassum, equipment for ocean farms and artificial upwelling technology in small-scale trials at sites in Mexico and St. Vincent, with further trials planned, probably off the coast of Cape Verde in spring 2023. The first pilot project is expected to take place later in 2023, probably near Ascension Island. Seafields plans to establish a 150 km² Sargassum spp. farm by 2025 and 65,000 km² until 2030, floating in the South Atlantic between Africa and South America.

C-CAUSE project – Germany
The publicly funded project Chemical CArbon Utilization through Sargassum Economy (C-CAUSE) was launched in Germany in 2022 and aims to provide a proof of concept for open ocean sargassum aquafarms, quantify and verify carbon sequestration from sargassum aquafarms, and convert harvested sargassum biomass into consumer products. To achieve this, C-CAUSE plans to implement an open ocean sargassum aquafarm pilot project in collaboration with Seafields Solutions Ltd. and CarbonWave.

Seaweed Generation Ltd – Caribbean
UK-based Seaweed Generation Ltd aims to develop robots to grow, capture and sink sargassum seaweed into the Deep Sea. The company has announced a first sargassum sinking pilot test in the Caribbean in 2023, with further growth in 2024, and expects "*our main source of revenue will be from carbon dioxide removal credits*".

Running Tide – Maine (USA), Iceland
Running Tide Technologies Inc. aims to grow seaweed such as kelp in large quantities in the open ocean and then sink it to the ocean floor. The project attached, kelp plants to biodegradable buoys made from forestry residues and coated with calcium carbonate, aiming to increase the alkalinity of the ocean. After several months of growth, the kelp plants are supposed to become too heavy and sink. In 2022, the Icelandic government granted the company a four-year permit to deploy buoys: up to 50,000 tonnes of buoys off the Icelandic coast, and up to a further 450,000 tonnes in international waters. The schedule and exact locations have not yet been disclosed. Scientists have raised concerns about the potential impact on marine ecosystems.

Pull to Refresh – California (USA), Panama
California-based Pull to Refresh plans to sink seaweed into the deep ocean, using semi-autonomous vessels to capture and lower the seaweed. The company plans to sell carbon credits on this basis. The company's first project is to sink sargassum in the Caribbean. A timetable and exact location for this project has not yet been disclosed. Since 2022, Pull to Refresh has a vessel manufacturing factory in Panama operational and aims to reach a capacity of ten vessels per day.

Brilliant Planet – Morocco, Oman
By the end of 2022, UK-based Brilliant Planet has raised a total of $26.7 million in four rounds of funding. The funds will be used to expand the 3 hectares pilot area in Morocco to 30 hectares by 2024. The company operates an algae production plant near the coast, harvests the algae and buries it under Saharan sand to sell carbon credits

on this basis.

The Climate Foundation – California, Philippines, Australia
The US-based The Climate Foundation (TCF) has developed a floating seaweed farming platform that uses wave-powered pumps to transport deep ocean water to the sunlit surface layers of the ocean. In 2022, TCF announced plans to develop a project in the Santa Barbara Channel area off the coast of Southern California in the eastern Pacific Ocean. TCF aims to build 100-hectare facilities off the coast.

TROFX – California
TROFX aims to combine seaweed cultivation in the open ocean with a wave-driven artificial upwelling system. The company is currently demonstrating a small-scale model project ten kilometres off the coast of New Hampshire in the Gulf of Maine. TROFX intends to build a larger offshore algae farm for biomass production using wave-driven artificial upwelling.

UPDATES ON CCUS PROJECTS WITH SEAWEED AND ALGAE

There are also plans to sequester CO_2 in processed macro- and microalgae products such as algae-based biofuels and fertilisers. CO_2 is generated during the production of the products and as soon as the products are consumed, for example as animal feed, the captured CO_2 is released back into the atmosphere. Read more about Carbon Capture Use & Storage here.

Blue3 – New Zealand
The San Francisco based Blu3 aims to sequester CO_2 with seaweed and commercialise blue carbon credits, algae-based biofuels and other consumer products. In October 2022, Blu3 "announced *signing a trans-Pacific deal with Te Huata Charitable Trust, which represents Te Whānau-ā-Apanui, a New Zealand Iwi (First Nations Tribe)*" on developing seaweed industry in the South Pacific off New Zealand.

Kelp Blue – The Netherlands, Namibia, Alaska, New Zealand
Dutch Kelp Blue aims to establish large-scale kelp plantations in coastal areas, including Namibia and Alaska. The company plans to cultivate 70,000 hectares of seaweed by 2029, 30 to 100 kilometres off the coast of Namibia.In late 2022, Kelp Blue announced plans to establish a kelp pilot farm and two commercial projects off the coast of New Zealand. The company aims to 'store' CO_2 in seaweed and produce kelp-based agricultural and consumer products.

Carbon Kapture Ltd. – Ireland
The UK-based Carbon Kapture Ltd. aims to establish kelp farms off the coast of the UK, and later expand globally. The first kelp farm was opened in northwest Ireland in late 2022/early 2023. Carbon Kapture plans to have one million metres of seaweed ropes in the water by the end of 2023. By building a global network of kelp farms, the company aims to remove CO_2 from the oceans and create "carbon negative products and services", including the sales of carbon credits.

Global Algae Innovation – Hawaii, California
In 2023, Global Algae Innovations plans to break ground for a 65 hectare algae farm in Shandon, California, aiming to capture 7,500 tonnes of atmospheric CO_2 per year. The algae harvested will be used to produce biofuels, polymers and other products.

Chitose Bio – Singapore, Malaysia
In 2023, Singapore-based Chitose Bio Evolution Pte. Ltd. plans to launch a five-hectare algae production facility in Malaysia and aims to develop, produce and market algae-based products including biofuels.

Neste: Algae to Fuel Initiative – Finland
Since 2022, Neste has been participating in the ROBA – Robust Algae Systems project, funded by Business Finland. ROBA aims to develop economically viable algae processes.

Pond Technologies – Finland
Pond Technologies is a developer of photobioreactors for microalgae production. In late 2022, the Ontario-based company formed Pond Carbon to market its production technology and carbon credits where a commercial production facility is used.

PLANNED EXPERIMENTS WITH REFLECTIVE MATERIALS ON ARCTIC AND GLACIAL ICE SURFACES

The Bright Ice Initiative, a company founded by Leslie Fields in 2022, has announced plans to conduct an outdoor trial to test a reflective cover material on the Chhota Shigri glacier in the Indian Himalayas. The field trial will run for three years from June 2023. The trial's scope and location have not yet been publicly disclosed. According to an emailed update from the Bright Ice Initiative, tests were conducted in Iceland and the USA in 2022 "*under simulated glacier conditions*" to prepare for the field trial in India. There is no further information available on the exact location, scope and duration of these two preparatory trials.

The Bright Ice methodology is based on the concept developed by Leslie Field with her company Arctic Ice Project, founded in 2007, and tested on frozen lake ice and Arctic ice. The Arctic Ice Project has also been planning a new field trial in Svalbard, Norway, since 2021. This was initially announced for March 2021, but then postponed to 2025/26. According to the company, the sites for the Svalbard field trial have already been selected.

The methodology was invalidated by a study published in October 2022 by Melinda Webster, University of Alaska, and Stephen Warren, University of Washington, that showed that the reflective silica glass accelerated rather than slowed melting. The study's author concluded that: "*The use of microspheres as a way to restore Arctic sea ice isn't feasible*".

In an interview with Leslie Fields in December 2022, she said: "*I'm never going to work where we're not wanted*". However, this is not in line with previous experience: under Leslie Fields' leadership, experiments have been conducted on Arctic ice without the consent of local communities.

OCEAN FERTILISATION AND ARTIFICIAL UPWELLING EXPERIMENTS RECENTLY PLANNED OR DISCLOSED

Ocean fertilization and artificial upwelling are both associated with numerous and sometimes unpredictable risks to the marine environment, including threats to the marine food web, oxygen depletion and potential transboundary effects on fisheries, coastal communities and weather patterns. For these reasons, the London Convention/London Protocol adopted a moratorium decision in 2008, and the United Nations established a de facto moratorium on ocean fertilisation through the Convention on Biological Diversity. In both cases, there are exemptions for small-scale scientific experiments.

OPR Madagascar, OPR New England, OPR Alaska
Among the players is OPR Madagascar, which wants to carry out ocean fertilisation in the Indian Ocean around Madagascar in order to monetise it in the form of 'blue carbon'. The project ignores the fact that ocean fertilization is banned due to the high risks to marine ecosystems and food chains. The principal actor behind this dump is Russ George, formerly CEO of Planktos, a company that had attempted to dump iron in the waters west of the Galapagos Islands and the Canary Islands in 2007. OPR has other sites. In November 2022, OPR New England announced plans to conduct ocean fertilisation in the Atlantic Ocean off New England in the summer of 2023 using shiploads of iron-rich dust. Russ George has announced a three-year ocean fertilisation project in the Gulf of Alaska, south of Kodiak.

WhaleX project – Australia
Off the coast of Australia, the WhaleX project has announced new ocean fertilisation experiments with nutrient solutions. The project was led by the University of Sydney until 2022. Since 2022, the Ocean Nourishment Corporation (ONC) is in charge and announced a "*1,000 tonne CO_2 removal experiment*" scheduled for 2023/2024 and mesocosm (large test tubes) studies in 2024.

Centre of Climate Repair at Cambridge (CCRC) – India, South Africa, Hawaii
The Centre of Climate Repair at Cambridge (CCRC) has reported on an ocean fertilization experiment that was conducted as early as April 2022. India's National Institute of Oceanography (NIO) in Goa conducted the experiment with buoyant flakes of a fertilizing substance in the Indian Ocean. Information on the scale, location and timeframe of the experiment(s) is not publicly available. Under the direction of the CCRC, the University of Cape Town is planning ocean fertilisation experiments in the Southern Ocean in January/February 2023, and the

University of Hawaii in the Pacific Ocean. According to the CCRC, "*Results from these preliminary experiments will inform large scale field trials in 2023-2026 to be undertaken by consortium members (led by CCRC), targeting all major ocean deep-water basins to inform potential global deployment starting in 2027.*"

Exploring Ocean Iron Solutions (ExOIS)
Exploring Ocean Iron Solutions (ExOIS) describes itself as an umbrella organisation that aims to investigate ocean iron fertilisation in the form of large-scale international open-ocean, laboratory and modelling studies. In 2022, ExOIS demanded "*larger (100's tons Fe over 1000's km^2) and longer field work (seasonal-years)"* and *"replication and studies in both high- and low-nutrient conditions*". ExOIS members include research institutions and companies, including the CCRC, Foundation for Climate Restoration, GEOMAR, Ocean Visions and Xiamen University.

Test-ArtUp – Canary Islands
In late 2022, the German research project Test-ArtUp tested a wave-driven artificial upwelling pump in the Atlantic Ocean, 260 kilometres south of the Canary Island of El Hierro. The upwelling pump was built by the US company Ocean-based Climate Solutions Inc.

DIRECT OCEAN CAPTURE: RECENT UPDATES ON FUNDING AND EXPERIMENTS

Direct ocean capture aims to remove CO2 from the ocean or other surface waters. The captured CO2 is to be stored either underground using Carbon Capture and Storage (CCS) or in products of varying durability with CCUS.

SeaChange – California, Singapore
The California-based start-up, SeaChange aims to develop and test an electrochemical process to capture carbon from seawater. The company had planned to pilot the technology in Los Angeles and in Singapore in 2022, but this has now been pushed back to 2023. In 2022, SeaChange received at least US$ 23.5 million in donations.

SeaCURE – UK
In 2022, the Sea Carbon Unlocking and Removal (SeaCURE) project announced the construction of a pilot plant in the UK, aiming to remove 100 tonnes of CO_2 from seawater per year. The UK government's contribution to the project is three million pounds.

Captura – California
Captura's pilot plant for the electrochemical removal of CO_2 from ocean water in Newport Beach, California, with a capacity to capture one tonne of CO_2 per year, has been operational since autumn 2022. A second pilot in the open ocean, with a capacity to capture 100 tonnes of CO_2 per year, has been announced for 2023. Preparations are underway. In January, Captura raised US$12 million in funding for this purpose.

U.S. Department of Energy (US-DOE) funding
In September 2022, the US-DOE announced up to $30 million in funding for R&D projects to advance CO_2 capture from both the atmosphere and oceans and converting it into valuable products such as fuels and chemicals.

Propeller (funding)
In October 2022, Propeller, a US-based climate tech fund, announced US$ 100 million in funding, including for oceanic CO_2 removal (direct ocean capture).

MARINE ENHANCED WEATHERING EXPERIMENTS RECENTLY PLANNED OR DISCLOSED

Enhanced weathering is a set of theoretical techniques to remove CO_2 by spreading large quantities of selected and finely ground rock material onto extensive land areas, beaches or the sea surface. This hypothetical CO_2 removal technology attempts to mimic and accelerate natural weathering processes. This would require mining, crushing, transport and distribution of large quantities of rock, which would involve high energy consumption, environmental damage from rock mining and unforeseeable risks to marine ecosystems.

Vesta – North Carolina, Great Lakes region, New York, Dominican Republic

Vesta's affiliate, Vesta North Carolina, PBLLC, seeks to test and scale enhanced weathering with olivine in the nearshore waters off Duck, North Carolina. The application for a permit for the experiment was submitted in 2022. Vesta hopes to deploy the olivine in spring 2023.

Vesta also has plans to deploy ground olivine in the Great Lakes region and is currently seeking partners. Vesta is currently running trials in New York and in the Dominican Republic and is actively seeking additional test sites around the world. The marine enhanced weathering activities have recently been marketed as 'Coastal Carbon Capture' and Vesta plans to operate *"Coastal Carbon Capture Carbon Credit Sales*".

RETAKE (CO2 Removal by Alkalinity Enhancement: Potential, Benefits and Risks) project – North Sea
The German research project RETAKE plans to conduct a field trial with mesocosms off the German North Sea island of Helgoland from March to April 2023.

Ocean alkalinity enhancement experiment in Apalachicola Bay, Florida
In May 2022, researchers from the University of Notre Dame injected 2,000 litres of lime-enriched seawater into an estuary in Apalachicola Bay, Florida.

TERRESTRIAL ENHANCED WEATHERING – CURRENT UPDATES

Lithos Carbon – USA
In October 2022, Lithos Carbon said that since the company's inception in March 2022, over 11,000 tonnes of finely crushed basalt rock had been spread on over 1,000 acres of farmland in the US for enhanced weathering, and that it had secured over US$ 6 million in a funding round.

Heirloom Carbon Technologies – California
The Heirloom Carbon process combines enhanced weathering and direct air capture. In 2022, Heirloom entered into a partnership with CarbonCure. CarbonCure uses the CO_2 captured by Heirloom in Brisbane, California, for concrete production.

Carbon Drawdown Initiative – Germany, Greece, the Netherlands
The Carbon Drawdown Initiative Carbdown GmbH is conducting research into enhanced weathering. Field trials are taking place in Fürth and Bremerhaven (Germany), Larissa (Greece) and Wageningen (The Netherlands). The field trials are accompanied by laboratory experiments and pot experiments in greenhouses.

CARBON CAPTURE AND STORAGE (CCS) – UPDATES

CCS aims to pump captured and liquefied CO_2 underground for theoretical long-term storage. However, most CCS projects use CCS for enhanced oil recovery, which involves pumping pressurised CO_2 into oil reservoirs to recover remaining reserves from ageing oil fields and to extract otherwise inaccessible oil. The carbon compressed underground could leak for many reasons, including faulty construction, earthquakes or other underground movements.

Global Status Report of CCS for 2022
In November 2022, the Global CCS Institute (GCCSI), an international organization that works to accelerate the development and deployment of CCS, published the Global Status Report of CCS for 2022. When compared with the Interactive World Map on Geoengineering Research Projects and Experiments, it is striking that the GCCSI statistics do not accurately reflect the number of cancelled CCS projects. For example, the GCCSI lists only two abandoned projects in the US, while the World Map on Geoengineering documents more than 50 known projects that have been abandoned or not pursued after a test phase. High costs and financing problems, technical problems and resulting delays are the most frequently cited reasons for abandoning CCS projects. The GCCSI statistic lists the CO_2 capture capacity of the CCS projects. The capacity given is the nominal capacity for most projects, but not the actual capacity. The actual capture capacity is often significantly lower than the nomal capacity.

US Taxpayers for Common Sense (TCS)

In December 2022, the Washington-based TCS criticised the use of public funds to support CCS, citing, among other things, mounting evidence that CCS is neither economically viable nor an answer to our environmental challenges, that CCS is largely untested and unproven as a strategy for reducing greenhouse gas emissions, and that CCS could leave taxpayers with long-term environmental liabilities.

44.01 / Project Fujairah – Oman, United Arab Emirates
In January 2023, the Oman-based company 44.01, the Abu Dhabi National Oil Company (ADNOC), the Fujairah Natural Resources Corporation (FNRC) and Abu Dhabi Future Energy Company (Masdar) announced a CO_2 mineralization pilot project in Fujairah, United Arab Emirates. The mineralisation project aims to use seawater and will be 44.01's largest pilot project to-date. Further details on the timing and size of the project have not yet been released. In December 2022, 44.01 won US$ 1.2 million in the Prince William's Earthshot Prize Challenge.

Ocean GeoLoop – Norway
In 2022, Ocean GeoLoop introduced its technology to capture CO_2 emissions from point sources and commissioned its first carbon capture pilot plant at Norske Skog's Skogn plant, a pulp and paper mill in Norway. Chevron U.S.A. Inc.announced a NOK 100 million investment in the company. In October 2022, Ocean GeoLoop signed a Letter of Intent for CO_2 capture with the fertiliser company Yara Norge AS in Herøya, Norway.

BIO-ENERGY WITH CARBON CAPTURE AND STORAGE (BECCS) – UPDATES

BECCS aims to capture CO2 from bioenergy applications and either store it through CCS or reuse it with CCUS. Large-scale deployment of BECCS would come with large-scale adverse impacts on the climate, ecosystems and biodiversity, as well as profoundly negative social effects.

Midwest Carbon Express – USA
Summit Carbon Solutions proposed the "Midwest Carbon Express". The BECCS project involves building a 2,000 miles pipeline network that will pump captured and liquefied CO_2 from more than 30 ethanol plants to North Dakota for underground injection. The project is facing growing opposition from Indigenous people, local communities, landowners and environmental groups, because of the health and environmental risks associated with CO_2 pipelines and because CCS has failed to reduce CO_2 emissions.

Heartland Greenway – USA
The Heartland Greenway BECCS project involves the construction of a 1,300-mile pipeline network to pump captured and liquefied CO2 from more than 30 ethanol or other industrial plants into the Mt. Simon sandstone formation in central Illinois. Like the Midwest Carbon Express, the Heartland Greenway faces growing opposition.

InBECCS project / C-Capture Ltd. – UK
In 2022, the UK-based InBECCS project announced plans to connect a BECCS plant to an existing 28.5 MW biomass gasification plant. The proposed CO2 capture technology comes from the British company C-Capture Ltd, a spin-off from the School of Chemistry at the University of Leeds.

SOLAR RADIATION MANAGEMENT (SRM) – UPDATES

SRM attempts to reflect sunlight back into space, including the proposal to spray large quantities of sulphur particles into an upper layer of the atmosphere to act as a reflective barrier to incoming sunlight. Computer simulations suggest that this technique would likely cause droughts and could endanger the source of food and water for two billion people.

Make Sunsets – Mexico
Make Sunsets was founded in October 2022 by Luke Iseman and claims to "*create reflective clouds in the stratosphere*". Starting in April 2022, the US company conducted two unauthorised test flights using weather balloons and sulphur near La Ventana, Baja California Sur, Mexico. Make Sunsets announced "*at least 3 balloons in January 2023*", but had to stop the experiments in Mexico because the Mexican government announced that it will not permit solar geoengineering experiments and will go so far as to stop geoengineering experiments in the country, if necessary. Make Sunsets wanted to sell 'cooling credits' based on the flights, but the company admitted

that it had no way of knowing whether the balloons reached the stratosphere and/or whether they released the sulphur. Due to the ban in Mexico, Make Sunsets switched locations and released three balloons containing sulphur particles in a park in Reno, Nevada in February 2023.

The Degrees Initiative

In December 2022, the UK-based The Degrees Initiative announced 15 new SRM research projects across the Global South. In 2018, eight research teams were funded under the programme, increasing to eleven in 2022.