Increased funds for Geoengineering – Quarterly Review III (part 1)

October 5, 2022

Photo Credit: JP Valery

By Anja Chalmin

Every day people in the United States, Canada and the UK are paying for some big new geoengineering projects in the form of publicly funded geoengineering projects. This, along with other new funding opportunities for geoengineering projects and companies is a key theme of the third quarterly review of current developments in geoengineering. The publicly and private funded programmes focus on geoengineering projects using direct air capture, enhanced weathering, carbon capture use and storage (CCUS) and marine geoengineering approaches. The programmes are thus investing in approaches that are fraught with great risks and unknowns, expensive, energy-intensive, unproven and irrelevant to emission reduction targets. The raison d'être of geoengineering technologies should be questioned not only because of the issues just mentioned, but also because they prolong the use of fossil fuels.

The second part of the third quarterly review looks at geoengineering developments on water and on land with a focus on marine projects, projects that aim to carbonise CO_2 and projects that seek to capture CO_2 using algae.

Extensive funding for geoengineering projects

This chapter features some of the new public and private funding initiatives for geoengineering. Much of the funding will go to direct air capture (DAC) and marine geoengineering projects. DAC requires extensive resources, especially a lot of energy, due to the inert properties of CO_2, and significant questions remain about what happens to the captured CO_2 to ensure it does not re-enter the atmosphere. If it is used for CCUS (carbon capture use & storage), for example for the production of fuels, the captured CO_2– after energy-intensive processing – is released back into the atmosphere after a short time, namely as soon as the fuel is consumed. Often, additional CO_2 is generated as a result. If it is used for CCS (carbon capture & storage), in many cases this means enhanced oil recovery (EOR) or enhanced gas recovery (EGR). EOR and EGR involve pumping pressurized CO_2 into oil or gas reservoirs to recover remaining reserves from ageing oil and gas fields and to extract otherwise inaccessible fossil fuels, thereby significantly increasing production. This technology was developed by the oil industry half a century ago to tap hard-to-reach deep oil reserves and it is now being marketed under a new name. If the captured CO_2 is injected below ground without EOR/EGR, the safety and durability of the storage is not guaranteed, proof that CO_2 can be safely stored under ground over the long term has not been provided. Long term storage seems unlikely in part because the tectonic movements of the earth's plates can cause cracks to form from which the injected CO_2 could escape, and also because most former fossil fuel deposits have been perforated for decades with boreholes

that have not been mapped.

Many of the approaches to marine geoengineering involve technologies to remove greenhouse gases, particularly CO_2, from the atmosphere, including ocean fertilisation, enhanced weathering, artificial upwelling or the proposal to dump biomass on the seabed. But there are other approaches as well: The Artic Ice Project is aiming to cover large areas of sea ice with a reflective substance. What these approaches have in common is that they are associated with numerous and sometimes unpredictable risks to the marine environment, e.g., threats to the marine food web, oxygen depletion, increased release of methane, potential effects on marine biochemical processes, harmful toxin-producing algal blooms as well as potential transboundary effects on fisheries, coastal communities and weather patterns. 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.

Many of the projects described are very energy-intensive and rely on renewable energies – which reduces the amount of renewable energy available to replace fossil energy sources. And despite the differences in approach, all the projects presented have one feature in common – they do not address the root cause of climate change.

Ocean Alkalinity Enhancement Research Award
The Ocean Alkalinity Enhancement Research Award was announced earlier this year by Additional Ventures, an organisation that aims to accelerate research progress in geoengineering. For the award, Additional Ventures has partnered with Ocean Visions, an organisation that supports the development and testing of geoengineering approaches to remove carbon dioxide from the ocean. The award is funded by Additional Ventures and other philanthropic funders including Astera, Builders Initiative, Grantham Environmental Trust, Oceankind and Thistledown Foundation. The call aims to develop and scale approaches to ocean alkalinity enhancement (OAE), a technology that aims to mimic and enhance natural weathering. The funding decision was announced for early August 2022, but was postponed. Funding will be provided for mechanisms to disperse alkaline substances in seawater, technologies to integrate OAE into existing marine and coastal industries, such as transoceanic shipping and commercial fisheries, among others. They are offering grants of US$ 0.75 to US$ 1.5 million to fund projects lasting up to 18 months. The total amount of funding available is at least US$ 10 million, to be used within five years.

Frontier Climate Fund
The Frontier Climate Fund is a carbon removal initiative founded in 2022 by Stripe, Alphabet, Shopify, Meta and McKinsey and also supported by Google and Facebook. The initiative aims to support carbon removal companies with an advanced market commitment to purchase CO_2 in order to accelerate the development of carbon removal technologies. To this end, the Fund has US$ 925 million available for the period 2022-2030. In late June 2022, the Fund announced a total of US$ 2.4 million for the first six selected early-stage carbon removal technology projects, decided by a 19-member panel of academics and industry. Three of the companies develop direct air capture (DAC) technology, two companies study enhanced weathering and one company uses CO_2 capture through genetically modified trees:

- **Australia's AspiraDAC Pty Ltd**, a subsidiary of Corporate Carbon, is developing a modular, solar-powered DAC technology. The solar power supply is directly integrated into the DAC modules and the CO_2 sorbent is based on a metal-organic framework structure. According to AspiraDAC, the DAC process requires little thermal energy and is cost-effective – but precise details on energy and resource consumption are not yet publicly available. The captured CO_2 is to be injected underground. With additional financial support from the Australian federal government, AspiraDAC has committed to building a DAC plant that will deliver ~310 tonnes of CO_2 per year; no information is yet available on the location and timeline.
- **Calcite-Origen** is a DAC joint venture between 8 Rivers (North Carolina, USA) and Origen (UK). The company was formed in June 2022 and aims to combine 8 Rivers' calcite carbon removal technology with Origen's ZerCal™ zero-carbon lime manufacturing process. The DAC approach uses lime (calcium hydroxide) to capture CO_2 from ambient air. The resulting carbonate minerals are heated to produce a concentrated CO_2 stream for geological storage. The joint project is planning a CO_2 capture plant in the UK to demonstrate the technology. No information is yet available on the location or timetable. The demonstration project is expected to capture ~1,000 tonnes of CO_2.
- **Israeli RepAir Carbon Capture** develops DAC technology based on a modular electrochemical approach. CO_2 is captured from ambient air using a membrane and an electrochemical cell. The process requires electrical energy. According to RepAir, the electrochemical cell operates at ambient temperature. How much

energy is needed to run the capture process and to release the captured CO_2 from the membrane is not yet published. The energy needed to run the plant is to be supplied from renewable energy sources.

- **US-based Lithos Carbon** seeks to spread finely crushed basalt rock on agricultural land for enhanced weathering. The company is modelling the process and planning field studies to measure the deposition of CO_2 and the effects of enhanced weathering on ecosystems. The modelling is being conducted in collaboration with Yale University and the Georgia Institute of Technology and aims to track the path of the fixed carbon, starting with on-farm application, runoff and erosion through rivers and streams, and ending with its entry into the ocean.
- **US-based Travertine Technologies Inc.** aims to further develop and commercialise an electrochemical process for CO_2 capture. According to Travertine, the process uses sulphate waste from mining and electrical energy, and converts CO_2 into carbonate minerals while producing sulfuric acid. The company is currently looking for partners to scale and pilot the technology at mining sites or with fertilizer manufacturers.
- **US-based Living Carbon** has set itself the goal of increasing CO_2 assimilation in and the growth of trees. To do so, processes around the plant enzyme Rubisco, which is responsible for CO_2 transport in plants, were genetically modified with DNA from other plants. In addition, the genetically modified trees are said to be able to accumulate metals more easily – to slow down wood decay and clean industrially degraded soils. Living Carbon claims that the genetically modified trees produce over 50% more biomass – but there is no peer-reviewed study to date to confirm this. Furthermore, the company does not yet address the risks associated with genetically modified organisms. By 2050, Living Carbon plans to plant 13 million hectares of land to reduce two percent of global emissions. Currently, an area with more than 600 genetically modified trees is planted in Corvallis, Oregon, and is being monitored in collaboration with Oregon State University's College of Forestry. Further planting sites are located at Reidsville, Georgia (~1,130 ha) and at Zion Grove, Pennsylvania (~120 ha).

Third Derivative's global climate technology accelerator: First Gigaton Captured initiative
In July 2022, Third Derivative partnered with the Grantham Environmental Trust to launch the First Gigaton Captured initiative, which aims to rapidly develop, scale, and commercialize carbon capture technologies. The following five companies were selected for funding:

- **Los Angeles-based AVNOS Inc.**, founded in 2021, is commercializing a new DAC technology developed at US-DOE's Pacific Northwest National Laboratory (PNNL). The new DAC approach is described as a hybrid DAC solution, because the technology captures CO_2 and water. The company states that it is an energy-saving technology – but details on energy and resource consumption have not yet been made public. The new DAC technology is called Isothermal Water Vapor and CO_2 Capture (IWVC). It works with a two-stage vacuum swing process. First, the device captures water vapor and CO_2. Then it condenses the water and compresses the CO_2 for carbon capture and storage (CCS) or carbon capture use and storage (CCUS). The technology will be tested in a US$ 3.2 million project in Southern California; the exact location has not yet been disclosed. The demonstration project is expected to capture 0.03 million tonnes of CO_2 per year and 0.36 million litres of water.
- **North Carolina-based Sustaera** developed DAC technology powered by renewable energy. According to Sustaera, its new modular DAC technology is cost-effective and can be used in a variety of locations, such as grasslands and deserts. Sustaera plans to capture one million tonnes of CO_2 per year in 2027 and 500 million tonnes of CO_2 per year by 2040 and is currently looking for potential project sites in Florida, Texas, California, Wyoming, North Dakota, Spain and Oman. The company is also looking for partners to provide renewable energy, develop joint carbon capture projects or buy captured CO_2.
- **San Francisco-based Vesta** (former Project Vesta) seeks to test and scale enhanced weathering with olivine – a soft, green volcanic stone – on beaches. Vesta plans to mine olivine, grind it into small pebbles and spread them on beaches where wave action is expected to support the weathering process. In July 2022, Vesta spread 650 tonnes of olivine on 130 metres of North Sea Beach, a beach north of Southampton on Long Island in eastern New York. And Vesta says it has received approval from the Dominican Ministry of the Environment for a first phase of outdoor experiments in two bays in the Dominican Republic. The planned tests include baseline research and experiments in so-called mesocosms (large test tubes in the sea). The start of the tests is currently announced for 2022.
- **UK-based company 44.01** was founded in Oman and aims to permanently mineralize CO_2 in peridotite rocks in Oman. Peridotite reacts with CO_2 and water to form the mineral calcite. In order to accelerate this years-long process, 44.01 injects highly carbonated water into the rock through targeted boreholes. 44.01

aims to mineralise one billion tonnes of CO_2 per year by 2040 and hopes to finance the project through carbon credits. For CO_2 capture, 44.01 has been in talks with DAC companies and has entered into collaborations with Switzerland's Climeworks and the UK's Mission Zero Technologies.
- **UK-based Mission Zero Technologies** plans to develop a new DAC technology based on an ion-selective electrochemical separation process that is expected to reduce the costs and energy requirements of DAC by 75%. The substances used in this process have not yet been disclosed, nor have precise details on energy consumption.

UK Department for Business, Energy & Industrial Strategy (BEIS) Direct Air Capture and Greenhouse Gas Removal technologies competition

In July 2022, BEIS published the projects selected for Phase 2 of its Direct Air Capture and Greenhouse Gas Removal programme. 15 projects have been selected to share over £ 54 million to further develop technologies to remove carbon from the atmosphere. Among them are the following marine or terrestrial projects:

- The project **Sea Carbon Unlocking and Removal (SeaCURE)** is led by the University of Exeter (UK) and aims to make seawater temporarily more acidic so that the CO_2 contained in the water "bubbles out". This CO_2 is captured, concentrated, compressed and then "stored". The water will be returned to the ocean, where it is supposed to be able to absorb new CO_2 from the air. The project aims to optimise this approach and test it in a pilot plant. In the long term, SeaCURE hopes to remove CO_2 on a megaton scale.
- **Dutch company CO2CirculAir BV** is developing a membrane-based DAC technology. CO2CirculAir BV proposes to use the captured CO_2 as feedstock for chemical products, fuels, carbonated drinks or greenhouses. This means that the captured – and possibly additional – CO_2 will soon be released back into the atmosphere.
- **UK-based Cambridge Carbon Capture Ltd (CCC)** develops a process to mineralize CO_2 into calcium carbonate and magnesium carbonate. The proposed process requires materials with calcium or magnesium ions. For this, CCC is aiming to use waste products such as ashes from incinerators, red mud from bauxite and slags from steel production. CCC aims to convert these wastes into solid building materials worldwide and is now looking for industrial partners to apply the developed technology.
- **UK-based Mission Zero Technologies (MZT)**, in collaboration with Optimus and O.C.O Technology, designed a DAC pilot plant based on MZT 's DAC technology in funding phase 1. In July 2022, the project partners received BEIS funding for phase 2, in which a working pilot plant will be constructed.

National and regional funding for carbon capture projects in Canada
In July 2022, the Canadian Government's Ministry of Natural Resources announced a CAD$ 81.5 million call to support research, development and demonstration projects in carbon capture, utilization and storage (CCUS). The call is funded under the national Energy Innovation Program, remains open until October 3, 2022 and represents the second call to support CCUS. In the first round of funding, eleven FEED (Front-End Engineering and Design) studies for large-scale projects were selected in April 2022, funded with CAD$ 50 million. Emissions Reduction Alberta announced additional CAD$ 40 million of public funding for carbon capture projects in the province.

Funding and tax credits for geoengineering projects in the United States
The Inflation Reduction Act (IRA) was passed in August 2022 and includes far-reaching commitments for the carbon capture industry. IRA increased the value of the 45Q tax credits created in 2008. The industrial carbon capture tax credit was increased from US$ 50 to US$ 85 per tonne of CO_2 captured, and the direct air capture tax credit was increased from US$ 50 to US$ 180 per tonne of CO_2 captured. The volume for DAC projects eligible for the 45Q tax credit has been reduced from 100,000 to 1,000 tonnes of CO_2 per year. IRA comes on top of last years Bipartisan Infrastructure Law Program, which includes large programs to demonstrate carbon capture, test and validate carbon storage, e.g., US$ 3.5 billion to develop four regional direct air capture (DAC) hubs, US$ 100 million for the United States Department of Energy (US-DOE) to plan pipelines for the transport of CO_2 to underground storage sites as well as US$ 2.1 billion in loans and grants for the private sector to build CO_2 pipelines.

In response to IRA,

- People vs. Fossil Fuels, a coalition of over 1,200 organizations campaigning for the end of the fossil fuel era, delivered a petition with more than 500,000 signatures to the White House, calling to declare a climate emergency to rapidly advance just, renewable energy, to end onshore and offshore drilling and to stop the federal approval of new fossil fuel projects and exports.

- The Indigenous Environmental Network stated that "*the Inflation Reduction Act (IRA) is a distraction from the need to declare a Climate Emergency, while allowing polluting industries to continue business as usual*".
- The Climate Justice Alliance compiled a list of threats, weaknesses and missed opportunities arising from IRA and concludes that "*the harms of the bill as it is currently written outweigh its benefits*" and that the IRA "*is not a climate justice bill*".

The extensive funding for direct air capture (DAC) in Northern America is having an effect: the number of DAC projects has more than doubled

In response to the extensive direct air capture (DAC) incentive programmes in the United States, the number of North American DAC companies and projects has more than doubled over the past years. Here is a selection of recent developments:

Los Angeles-based **CarbonCapture** was founded in 2019 and is developing a technology to capture CO_2 directly from the air, based on solid sorbents. The sorbents release the captured CO_2 when heated. The technology comes in container-sized modules. The company plans to use renewable energy to provide the power for the energy-intensive DAC processes. CarbonCapture aims to store the captured CO_2 underground (CCS) or use it to make products that require pure CO_2 (CCUS). In September 2022, CarbonCapture announced **Project Bison**. Project Bison will be implemented in Wyoming and funded with the DAC project tax credit, which was increased in 2022 by the Inflation Reduction Act (from US$ 50 per tonne to US$ 180 per tonne).

North Carolina-based **Sustaera** was founded in 2021 and develops DAC technology powered by renewable energy. Sustaera plans to capture one million tonnes of CO_2 per year in 2027 and 500 million tonnes of CO_2 per year by 2040 and is currently looking for partners and potential project sites in Florida, Texas, California, Wyoming, North Dakota, Spain and Oman.

US-DOE's Pacific Northwest National Laboratory (PNNL) has developed a new DAC technology and founded the company **AVNOS Inc.** in 2021 to commercialise the new technology. The new DAC approach is called Isothermal Water Vapor and CO_2 Capture and is a hybrid DAC solution – the technology captures CO_2 and water. AVNOS Inc. plans to demonstrate its DAC technology in 2023. The demonstration project will be based in Southern California and is expected to capture 0.03 million tonnes of CO_2 per year and 0.36 million litres of water.

Calcite-Origen was formed in June 2022. The company's DAC approach uses lime (calcium hydroxide) to capture CO_2 from ambient air. The resulting carbonate minerals are heated to produce a concentrated CO_2 stream for geological storage. Calcite-Origen plans to demonstrate the technology in the UK. The demonstration project is expected to capture ~1,000 t of CO_2. No information is yet available on the location and timetable.

SeaChange was formed based on research conducted at the University of California and founded to commercialise the research. The SeaChange DAC process extracts CO_2 from seawater and converts it into carbonates. The company aims to pilot its technology in Los Angeles and in Singapore in 2022.

The California-based company **AirCapture LLC** developed a modular DAC system to deliver captured CO_2 where it is needed, primarily to avoid transport costs and impurities. The company's technology adsorbs CO_2 from air blown by fans across chemical contactors. The concentrated CO_2 is then desorbed using low-temperature steam. In April 2022, the US-DOE awarded a combined US$ 14 million to five teams for DAC projects. AirCapture is a partner in two of the funded projects. One project is led by the Battelle Memorial Institute and located at Southern Company's Joseph M. Farley nuclear power plant in Columbia, Alabama. The nuclear plant provides the steam to desorb the captured CO_2. The captured CO_2 will be separated for geological storage (CCS) at this site. The second project is led by AirCapture LLC and will be based at Nutrien's Kennewick fertilizer operations facility in Kennewick, Washington. At this site, the heat of the fertilizer plant is used to separate CO_2 from the chemical contactor. The project plans to convert the captured CO_2 into chemicals (CCUS).

The Canadian DAC developer **Carbon Engineering Ltd.** is a project partner in another US-DOE funded project, led by Constellation and located at Constellation's **Byron Generating Station** in Byron, Illinois. The nuclear reactor provides the energy to capture CO_2 from ambient air. The captured CO_2 is separated for geological storage (CCS).

Mosaic Materials developed a DAC technology for CO_2 capture that uses so-called metal-organic frameworks, which are highly porous, crystalline solids with a large surface area . In April 2022, Baker Hughes acquired Mosaic Materials to further develop and scale its DAC approach.

1PointFive, a joint project between Carbon Engineering, Oxy Low Carbon Ventures, a subsidiary of Occidental, and Rusheen Capital, plans to build a commercial DAC plant in the Permian Basin, near an Occidental oil field in Ector County, Texas. Construction was scheduled to begin in 2021 and has since been pushed back to 2022. 1PointFive already sold CO_2 to Shopify and Airbus. By 2035, Occidental and its subsidiary 1PointFive intend to build 70 DAC plants worldwide.

The San Francisco-based **Noya Inc.** is a DAC – CO_2 removal business. Noya's approach is to retrofit existing infrastructure – cooling towers – with its DAC technology. Cooling towers are located on buildings and dissipate heat from air conditioning and similar systems into the atmosphere. Noya aims to retrofit the cooling towers with its DAC technology and sell the captured CO_2 as a product or use it to make new products (CCUS).

In 2021, Highly Innovative Fuels Global (**HIF Global**), a company that aims to produce synthetic fuels from captured CO_2, water and energy, announced plans to develop an eFuels production facility in Texas, USA. **HIF USA**, a subsidiary of HIF Global, plans to start the construction phase in 2023, commercial operation is scheduled by 2026. The exact location of the commercial plant is not yet known.

Capture6 is based in Berkeley, California and in Rotorua, New Zealand. The corporation is developing DAC technology. Capture6's DAC approach is powered by renewable energy and converts CO_2 into carbonates using sodium hydroxide as a CO_2 absorbent. Capture6 is currently looking for partners and investors to scale and further develop its DAC technology.