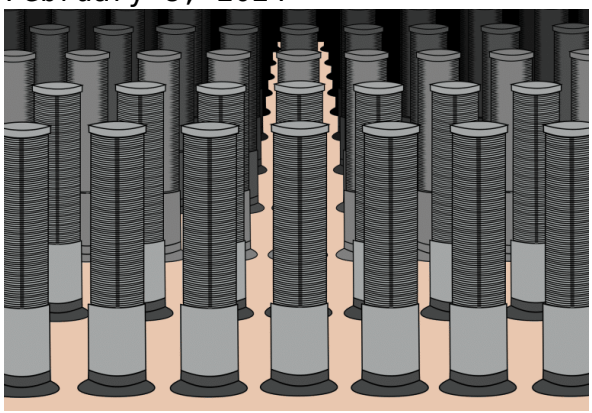
They can’t see the wood for the MechanicalTrees™: Recent Direct Air Capture projects are more successful at capturing funding than carbon

February 8, 2024



*This Update on **Direct Air Capture (DAC)** technologies summarises the latest developments on the Geoengineering Monitor Map, highlighting new trends for civil society and climate justice movements to follow in their efforts to oppose geoengineering globally. See here for other recent map updates, and here for a list of acronyms and abbreviations used in this update. This update is Part 3 of a three-part update on CCS, CCUS and DAC. It was researched and written by **Anja Chalmin**, and published with the support of the Geoengineering Monitor team.*

In this update:

Critical developments in DAC covered in this Geoengineering Map Update

- Irish company Carbon Collect is looking to commercialise its “mechanical trees” technology for capturing CO_2 with the help of millions of dollars in public funding, and says its trees are 1,000 times more effective

than real ones.

- Increasingly large amounts of public funding are being directed towards DAC projects, especially via US-DOE federal grants, including US$ 600 million for Project Cypress, US$3 million for a consortium including Removr, and almost US$ 10 million for various AirCapture LLC projects.

- Selling carbon credits is another driving force behind DAC, and many DAC projects are already being financed by or have been set specifically up to generate revenue in this way. Examples include Deep Sky, RepAir Carbon, Capture6, and 1PointFive.

- DAC companies are marketing their approaches as breakthrough innovations even though many of them have been in development for decades and have still not been able to demonstrate that their technologies are scalable and effective.

- Small projects that can make no meaningful contribution to the Paris Agreement's 1.5°C target are increasingly being referred to as large-scale, industrial and/or commercial projects.

- There is still no guarantee that DAC projects can permanently remove CO_2 from the atmosphere, given that captured CO_2 is either to be injected underground (CCS), which involves significant risks and uncertainties, or used in consumer products (CCUS), where the CO_2 is usually released back into the atmosphere on very short timescales.

Carbon Collect and its mechanical tree farms

The devastating wildfires that have struck parts of Chile once again are a tragic reminder of the dangers of huge expanses of monoculture tree plantations, especially when they replace natural forests that are so much better at slowing the spread and reducing the intensity of fires. Now though, a new and even more dystopian threat to the landscape looms: With the help of millions from the US Department of Energy (and more on the way), Irish company Carbon Collect Ltd is trying to commercialise mechanical tree plantations in order to suck carbon out of the atmosphere. What could possibly go wrong?

The number of DAC startups is growing exponentially, and more DAC companies have been created since 2020 than in all of the years before. What stands out about Carbon Collect though is the unusual shape of its DAC module. Its column-shaped "mechanical trees" are about ten metres tall, and they intend to build MechanicalTree™ farms starting in the second half of the 2020s, with literally thousands of these modules in huge industrial parks.

Carbon Collect was founded in 2018 with the aim of commercialising its "passive DAC" technology, which requires wind to operate. The technology is based on two decades of R&D at Arizona State University (ASU), but to date only one mechanical tree has been installed on an ASU campus. Despite this, Carbon Collect continues to describe its mechanical trees as "*a radical breakthrough in carbon capture*" that"*sets a new benchmark for capturing CO_2 from ambient air*". The mechanical tree farms concept has relied on public funding, and the US-DOE has provided US$ 2.5 million for the initial designs of three "commercial-scale" DAC operations, all in the US. In 2023, the

company and its partners were also shortlisted to design a regional DAC hub in Arizona, with US-DOE funding of US$ 12.5 million.

It is ironic that an Irish company should be looking to build mechanical trees, given that the country has one of the lowest levels of forest cover in Europe. Even its recently-announced national strategy to increase forest cover to 18% would still be well below the European average. In contrast, Carbon Collect's approach is to cover land with DAC modules. According to the company, capturing one million tonnes of CO_2 per year would require more than 20 km² of land and almost 1.5 million tonnes of fresh water, as well as additional resources such as the production and disposal of the sorbent material that the modules require. Estimates of the amount of steel and other construction materials that would be needed, and the emissions that construction and maintenance would be responsible for, have not yet been published (and the company has refused to respond to requests for this information).

The company does compare its DAC modules to forests, but only by reducing the comparison purely to CO_2 absorption rates: "*The MechanicalTree™ is a thousand times more efficient than natural trees at removing CO_2 from the atmosphere*". This ignores the myriad other ecosystem services that a real forest ecosystem provides, but which a DAC "tree" farm cannot, including climate and water regulation, water purification, erosion control and soil formation and, of course, a home for flora and fauna. Real forests also provide sustenance and livelihoods for millions of forest-dependent peoples, which DAC tree farms could never do. According to the IPCC, protecting and restoring forests and other ecosystems has the greatest climate mitigation potential of any option on the table. You have to wonder if Carbon Collect's efforts – and the millions it is receiving in public finance – could be better spent restoring Ireland's native forests.

Apart from the design of its DAC module, Carbon Collect is representative of the DAC market in many other ways:

- Its modular DAC technology is based on years of publicly-funded academic research for initial and advanced design studies, costing taxpayers millions of dollars;
- Only a few of its DAC modules are in operation, despite a long R&D phase and considerable resources;
- Although sorbent-based CO_2 capture technologies are not a new invention, the technology is described as a radical breakthrough;
- The company does not provide any data on energy consumption or a life cycle analysis of the total impact of its technology, and is not planning to have these factors independently assessed;
- The company's transition to "commercial scale" DAC operations has been consistently delayed and would only capture very small amounts of CO_2 anyway;
- The company plans to use the captured CO_2 in consumer products (CCUS), where it would be released back into the atmosphere almost immediately via an energy-intensive process, or inject it into underground geological formations (CCS), which involves high risks and costs.

Carbon Collect's vision of the future, with kilometres upon kilometres of giant metal towers dominating the landscape, is a great example of how misguided such geoengineering and technological approaches to climate mitigation are. It also illustrates how millions in public funding is being squandered on research projects that in all likelihood will cause more problems than they solve. Worse still, not only is this type of "climate solution" incapable of contributing to the Paris Agreement's target of limiting global temperature rises to 1.5°C, it is distracting from the real and proven solutions that can.

Other recent developments in DAC

Canada – Deep Sky

Deep Sky was founded in 2023 and raised CAD 75 million in the same year. It plans to have its Alpha pilot plant operational by summer 2024. The facility will be used to demonstrate onshore and offshore DAC technologies which are being developed and commercialised by more than ten different companies, mostly from Europe and North America. The demonstration tests are intended to form the basis of Deep Sky's plan to build large-scale DAC infrastructure in Quebec, Canada, to capture CO_2, and inject it into geological formations such as saline aquifers and ultramafic formations .

Deep Sky's funding strategy is based on lobbying for government financial support and, similar to most DAC companies, the sale of carbon credits . The environment and society do not benefit from the sale of carbon credits, and in fact the impacts of projects that sell them may even be negative. This is due to the fact that they are often too small to have any effect on reducing emissions, they often cause collateral damage, and delay the phase-out of fossil fuels. The only benefit to be gained is on the part of the seller financially, and the buyer in terms of greenwashing potential.

Canada – DAC developer acquired by oil and gas giant

In 2023, Canadian DAC technology developer Carbon Engineering was acquired by Occidental Petroleum for US$ 1.1 billion. Occidental is an international oil and gas company and the largest oil producer in the US Permian Basin. Carbon Engineering was founded in 2009 by David Keith, Professor of Applied Physics at the Harvard School of Engineering and Applied Sciences, with the aim of commercialising DAC technologies.

Germany – Greenlyte Carbon Technologies GmbH (GCT)

GCT was founded in 2022, but the company's DAC technology is based on 15 years of DAC research at the University of Duisburg-Essen, Germany. The energy-intensive process involves a liquid CO_2 capture agent and an electrolysis process to produce CO_2, H_2 and O_2. GCT proposes to use the captured CO_2 and H_2 in consumer products such as synfuels. The captured CO_2 returns to the atmosphere once the synfuel is consumed, and additional emissions may be generated during the DAC and manufacturing processes.

In 2023, GCT completed the construction of its Greenberry 2 demonstration project, which is capable of capturing up to 100 tonnes of CO_2 per year. The company says it wants to roll out "*commercial DAC plants in various sizes to reach 1 MT in 2035*" and one gigatonne in 2050. Like many other geoengineering projects, the capture of small amounts of CO_2 is being promoted as a commercial endeavour, but the timing and scale of the project does not

contribute in any way to the Paris Agreement's 1.5°C goal.

Since 2022, GCT has raised a total of € 8 million and five years of R&D have been made possible through public funding. Nevertheless, Florian Hildebrand, one of GCT's founders, says that "*if we don't watch out, climate tech will be invented in Germany and scaled in the US*" and calls for a "*better incentive structure in Europe*".

Israel – RepAir Carbon

RePair Carbon Capture, headquartered in Israel, aims to commercialise a modular DAC capture approach based on DAC research conducted at the University of Delaware, USA. In November 2023, RePair announced the completion of a prototype to demonstrate its DAC technology. The electrochemical process binds CO_2 in the form of carbonate and bicarbonate, and then reverses the binding process using a selective membrane. The company claims that its technology requires 600 kWh to capture one tonne of CO_2. There is no independent confirmation of this, nor any information on the performance of the prototype. RepAir promises "*carbon removal at the gigaton scale*" and aims to produce "*carbon removal credits of the highest quality*". It has already launched a carbon credit pre-purchase programme in partnership with the carbon markets Early Adopters, Frontier and Stripe. The company seems unconcerned about the fate of the CO_2 it captures, at least in its public presentation. Its focus is on generating income from carbon credits.

Two proposed DAC projects in Kenya's Rift Valley

In July 2023, Octavia Carbon, a developer of DAC technology in Kenya, announced a partnership with US-based Cella Mineral Storage and the joint 'Project Hummingbird'. The project aims to combine DAC and CC(U)S in Kenya's Rift Valley. In September 2023, Octavia Carbon entered into a partnership with the carbon market Klimate.co for the future sale of carbon credits.

In the same month, Swiss DAC technology developer Climeworks AG and Kenyan venture company Great Carbon Valley also announced plans for a joint DAC project in Kenya. The project aims to capture CO_2 from ambient air using Climeworks' DAC technology and inject the captured CO_2 into geological formations in Kenya's Great Rift Valley (exact location not yet known). The project is expected to be operational in 2028.

Norway, Iceland, USA – Removr

Oslo-based Removr aims to commercialise GreenCap's DAC technology. GreenCap has been developing the technology since 2016, testing it in four proof of concept trials and patenting the technology. The DAC approach uses microporous zeolite as a solid CO_2 sorbent and the captured CO_2 is desorbed using heat.

In 2022, Removr announced an "*industrial DAC pilot*" at the Mongstad Technology Centre in Norway. In 2023, the pilot was postponed to 2024. It is funded by the Norwegian government and aims to capture 300 tonnes of CO_2 in 2024, rising to 30,000 tonnes in 2027.

In 2022, Removr also announced plans to develop its first one million tonne DAC plant with Carbfix in Iceland

in 2027. By May 2023, Removr was no longer talking about one million, but of 0.1 million tonnes of CO_2 capture capacity per year. In December 2023, the target was further reduced to 0.05 million tonnes. The project is expected to start with a 0.002 million tonne "*commercial plant*" in 2025.

Removr is part of a consortium that was awarded has applied for US-DOE funding to develop a DAC hub in the US Pacific Northwest in August 2023. In December 2023, Removr announced plans to develop a one million tonne facility in the US, with the aim "*to capture attractive incentives for DAC currently offered by the US Inflation Reduction Act and sell high-quality, durable carbon dioxide removal (CDR) credits*".

Oman – US-based Air Capture joins Project Hajar

Project Hajar aims to capture CO_2 and inject it into geological formations in Oman. The project was launched in 2022 by Omani company 44.01 and DAC developer Mission Zero Technologies (MZT). The aim of the project was to capture CO_2 using MZT's DAC technology, and 44.01 was to be responsible for the subsequent injection of captured CO_2 into geological formations in the Al Hajar mountains in Oman. Since 2023, the joint project website of MZT and 44.01 is no longer active. AirCapture LLC, another developer of DAC technology, became 44.01's new partner in September 2023. Project Hajar is expected to be operational in late 2024.

The Netherlands – Skytree

Amsterdam-based Skytree B.V. Europe is marketing a modular CO_2 capture technology developed by the European Space Agency. The approach is based on a plastic resin that can absorb CO_2 and H_2O. Once saturated, the captured CO_2 can be released using heat and the resin can be reused. Skytree proposes to use its modular technology for indoor applications, including buildings, car cabins or for indoor farming. In October 2023, Skytree launched its Skytree Cumulus DAC module, which can capture up to 7,000 tonnes of CO_2 per year. In 2023, the company received € 5.5 million in seed funding (led by Horticoop and Yield Lab Europe) and a € 2.5 million award from the European Innovation Council Accelerator.

USA – Ankeron Carbon Management Hub

In 2023, the US-DOE provided funding to evaluate the feasibility of an electrically-powered DAC hub. The Ankeron Carbon Management Hub will be located in the Pacific Northwest (Idaho, Oregon, Washington) – the exact location is not yet known. The project will be led by the Rocky Mountain Institute in Basalt, Colorado, in collaboration with DAC technology developers Heirloom, Removr, and Sustaera. Iceland's Carbfix and the Pacific Northwest National Laboratory will conduct a feasibility study to test CO_2 injection into geological formations in combination with CO_2 mineralisation.

USA – CarbonCapture: Carbon credit sales and Project Bison

In 2023, DAC technology developer CarbonCapture entered into agreements to sell carbon credits with Amazon, Boston Consulting Group, Frontier and Microsoft Corp. and announced an equity investment from Amazon, although its DAC technology has not yet been demonstrated. In 2022, CarbonCapture announced Project Bison. The project aims to capture CO_2 from ambient air and to inject the captured CO_2 into geological formations. In

September 2022, the project website announced the goal of capturing 0.01 million tonnes of CO_2 from 2023 to 2024, 0.2 million tonnes from 2025 to 2026, one million tonnes from 2027 to 2028, and five million tonnes from 2029/2030 (can still be found in press reports). By the end of 2023, this information was no longer available on the project website and the project appears to be delayed. The project will be located in Wyoming, but no further information is available on the exact location, start of construction, or energy sources. The DAC project will be financed by public funds and the sale of carbon credits.

USA – Capture6's Project Monarch

California-based DAC technology developer Capture6 Corp. announced plans to launch its first demonstration project in 2023. Project Monarch is a collaboration with the Palmdale Water District (PWD) and will be implemented at PWD's Pure Water Antelope Valley demonstration facility, a water treatment plant in Los Angeles County, California. In July 2023, Project Monarch received an US$ 8 million grant from the California Energy Commission and in December 2023, an additional US$ 0.15 million grant from the US-DOE. In July 2023, Capture6 signed a first pre-purchase agreement for the sale of carbon credits with Kakao Impact and in November 2023, with the carbon markets Respira and Terraset. Although not yet tested at demonstration-scale, Carbon6 describes its technology as a "*game-changing technology*", and a "*world's leading solution*" promising "*permanent and irreversible carbon dioxide removal*" and *"to reach gigaton scale within 20 years"*. Capture6 also announced plans to launch projects in New Zealand, South Korea and in the UAE.

USA – Heirloom Carbon Technologies

Heirloom Carbon Technologies is a California-based developer of DAC technology. In 2023, the company partnered with the EU-funded Leilac research programme to improve its DAC technology. In the same year, the company announced its participation in the US-based Project Cypress, which is being funded by the US-DOE with up to US$ 600 million. As a result, Heirloom has signed an agreement with Microsoft to sell carbon credits and sold more than US$ 26 million in carbon credits to Frontier. Frontier's buyers include Autodesk, H&M, JPMorgan, Mckinsey, Meta, Shopify, Stripe and Workday. In November 2023, Heirloom unveiled its Tracy facility, which has the capacity to capture 1,000 tonnes of CO_2 per year, describing it as a "commercial" project.

USA – AirCapture LLC

In August 2023, the US-DOE awarded the Southeast Direct Air Capture (SEDAC) Hub grant to Aircapture LLC. AirCapture's DAC technology will be funded as part of a FEED study, with a target of capturing 0.05 million tonnes of CO_2 per year in Phase 1 and 0.5 million tonnes in Phase 2. The Hub will be located in Mobile County, Alabama. The US-DOE has already awarded AirCapture millions of dollars in funding, including for DAC projects at Southern Company's Joseph M. Farley nuclear power plant in Alabama, Nutrien's Kennewick Fertilizer Operations in Washington, the National Carbon Capture Center in Alabama, and a project with Hyundai Innovation North America. AirCapture is one of the geoengineering companies that paint a bright future for CO_2 capture ("*the commercial CO_2 industry projected to reach $6Tn by 2050*"), but so far it is only involved in small-scale trials or planned projects.

USA –1PointFive: Stratos Project

In 2023, Occidental's subsidiary 1PointFive sold carbon credits to Amazon, Houston Astros, Japanese airline

All Nippon Airways and Toronto-Dominion Bank to finance its Stratos project. In November 2023, the investment company BlackRock formed a joint venture with Occidental and announced a US$ 550 million investment in Stratos. The project, currently under construction, is expected to capture 0.5 million tonnes of CO_2 annually and plans to inject the captured CO_2 into saline formations in Ector County, Texas.

USA –1PointFive: US-DOE funding for Kleberg County Project

The project is conducted by Occidental's subsidiaries 1PointFive and Carbon Engineering and will be located near industrial emitters in Kleberg County, Texas. At this site, Occidental plans to construct 30 DAC plants with a planned CO_2 capture capacity of one million tonnes per plant per year. In August 2023, the US-DOE selected the project for funding of up to US$ 600 million. With this funding, the project is expected to capture up to one million tonnes of CO_2 annually and inject it into a saline geological formation.

USA – Project Cypress

In August 2023, the US-DOE selected Project Cypress for funding of up to US$ 600 million. With this funding, the project is expected to capture up to one million tonnes of CO_2 annually and inject it into geological formations. Project Cypress was announced in 2023 and will be conducted by Battelle in cooperation with Climeworks Corp. and Heirloom Carbon Technologies Inc. The project aims to combine DAC and CCS and will be located in Sulphur, West Calcasieu Parish, Louisiana. The project is expected to break ground in 2024, with construction continuing until 2029.

USA – Red Rocks DAC Hub

Fervo Energy's primary goal is to establish geothermal energy as a major source of electricity. In 2023, the US-DOE provided funding to evaluate the feasibility of a DAC hub that would combine geothermal-powered DAC, transportation of captured CO_2, and injection into geothermal reservoirs in southwestern Utah. The Red Rocks DAC Hub project is being led by Fervo Energy in collaboration with DAC technology developer AirMyne, the Utah Geological Survey, the University of Utah Energy and Geoscience Institute, and the Electric Power Research Institute. According to the US-DOE, the project aims to "*explore a direct air capture hub with the potential to store up to 100 million tonnes of carbon dioxide annually*" in southwestern Utah. In the same year, the company also announced a grant from the Chan Zuckerberg Initiative, a philanthropy run by Facebook, to design and engineer a combined geothermal and DAC plant and to explore the potential of geothermal reservoirs for injecting captured CO_2 underground. Fervo has also established a Technical Advisory Board for carbon removal, including representatives from a carbon market and the fossil fuel industry.

Abbreviations

ADNOC	Abu Dhabi National Oil Company
CCS	carbon capture & storage
CCUS	carbon capture use & storage
CO_2	carbon dioxide
DAC	direct air capture

FEED	front-end engineering design (study)
H_2	hydrogen
O_2	oxygen
R&D	research and development
UAE	United Arab Emirates
US-DOE	United States Department of Energy