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News & Highlights

Funding Bonanza Lifts CO_2 Removal Technology to Demonstration Phase

Sarah C.P. Williams

Senior Technology Writer

At the November 2022 United Nations Climate Change Conference of the Parties (COP27) in Sharm el-Sheikh, Egypt, a coalition of national governments—including the United States, European Commission, Japan, the United Kingdom, and Norway—announced a coordinated global effort to ramp up CO_2 removal (CDR) technology by investing billions of US dollars in demonstration projects. Their Mission Innovation Launchpad aims to build, by 2025, multiple direct air capture (DAC) hubs around the world, each capable of removing at least 1000 tonnes of CO_2 directly from the atmosphere annually [1].

The announcement came on the heels of a flurry of other policy and funding boosts aimed at promoting CDR technology over the previous year. In April 2022, an alliance of Silicon Valley companies—including Google, Meta, Shopify, and Stripe—made an advance market commitment of 925 million USD for carbon removal credits [2]. The same month, the 100 million USD XPRIZE Carbon Removal competition, funded by Elon Musk and the Musk Foundation, awarded its first 1 million USD Carbon Removal prizes to 15 teams from around the world, with another 80 million USD slated to be awarded in 2025 [3]. In August 2022, the US Inflation Reduction Act became law, boosting tax credits for carbon removal, capture, and storage [4], and in November the Carbon Removal and Emissions Storage Technologies Act of 2022 (CREST Act) was introduced to the US House of Representatives, following a Senate version in June; the law aims to expand the CDR development efforts of the US Department of Energy (DOE) [5]. In December, a draft report by the National Oceanic and Atmospheric Administration (NOAA) echoed other statements, calling CDR "essential" to meeting climate goals and outlining strategies for NOAA to expand their CDR strategies [6].

"The recent investments in carbon removal have been record breaking," said Ben Rubin, executive director of the Carbon Business Council, a Washington, DC, USA-based non-profit trade association focused on CDR. "The money is flowing from venture capital, and it is coming from philanthropic investments and both government and corporate support."

The funding and increased attention, Rubin said, stems in large part from the emerging consensus among climate change scientists that cuts to carbon emissions cannot happen fast enough to halt the potentially devastating consequences of the expected increase in global temperature in the coming decades, requiring CDR to work in tandem with the crucial work of reducing emissions (Fig. 1). An April 2022 report by the United Nations' Intergovernmental Panel on Climate Change (IPCC) included, for the first time, an entire chapter on CDR. The document highlighted the technology as a necessary component to counterbalancing carbon emissions and reaching atmospheric CO_2 reduction goals by mid-century [7]. The report stopped short, however, of endorsing any specific CDR technology. CDR approaches include planting trees, restoring wetlands, and burning plant matter then siphoning away the released carbon. The CDR technology seen as most scalable, however, is DAC, which filters CO_2 directly out of the air—anywhere on the planet—and then stores the captured carbon in rocks, minerals, soil, synthetic materials, or deep in the ocean, among other places (Fig. 2) [8,9].

DAC technology, though, is far from where it needs to be (Fig. 3) [8]. The IPCC estimates that to limit global warming to 1.5 °C—a goal stated in the Paris Agreement signed by world leaders in 2016—hundreds of gigatonnes of CO_2 in total must be removed from the atmosphere [10]. As of September 2022, however, there were 18 DAC plants operating worldwide, collectively capturing just 10 000 tonnes of CO_2 per year [11]. "One word to describe the field of carbon removal right now is 'nascent'," said Gaurav Sant, Pritzker Professor of Sustainability and director of the Institute for Carbon Management at the University of California, Los Angeles (UCLA), CA, USA. "There is a lot more aspiration and ambition than significant, industrial scale progress."

Under Sant's leadership, the Los Angeles-based startup company CarbonBuilt won 7.5 million USD in 2022 in the XPRIZE Carbon competition (a separate contest from the XPRIZE Carbon Removal sponsored by the Musk Foundation) jointly sponsored by NRG Energy (Houston, TX, USA) and Canada's Oil Sands Innovation Alliance (COSIA; Calgary, AB) [12]. The contest challenged researchers to convert CO_2 emissions into useable products; in a 2020 demonstration project, CarbonBuilt successfully captured emissions from a coal power plant in Wyoming using a method developed by Sant and colleagues for infusing and permanently trapping CO_2 in concrete [12].

Sant is not overly attached to one approach, however. He also recently founded the startup SeaChange (Los Angeles, CA, USA), based on technology he and colleagues developed that traps CO_2 via and within seawater in the form of dissolved bicarbonate species, and solid limestone. In August 2022, SeaChange won 735 000 USD from the Liveability Challenge, sponsored by the Singapore-based Temasek Foundation [13]. In October 2022, SeaChange announced that two pilot systems testing the technology will

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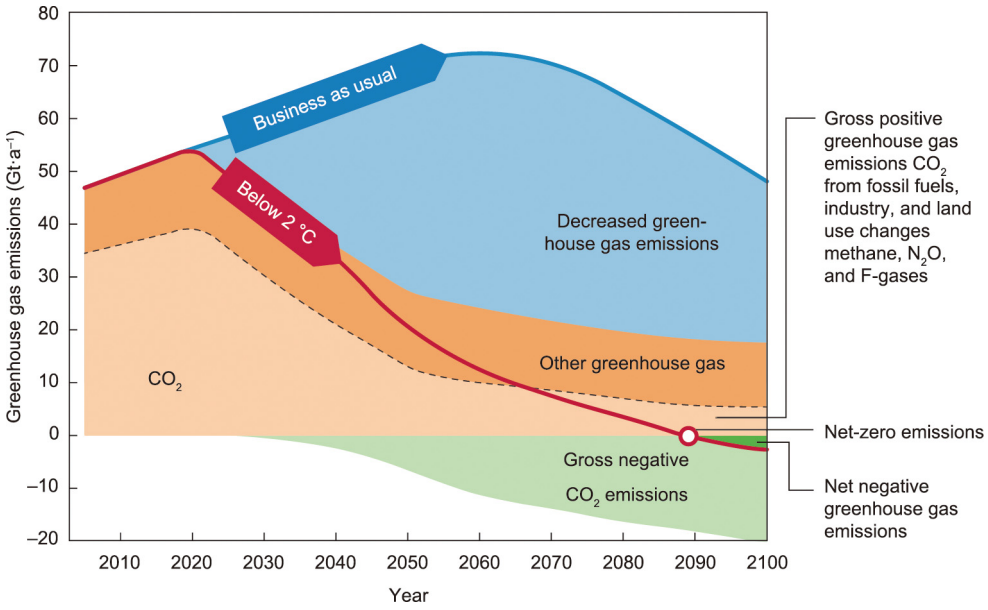

Fig. 1. Most climate change scientists now agree that, even with rapid and dramatic reductions in greenhouse gas emissions, carbon removal technologies (in green) will be necessary to remain below a 2 °C rise in global temperature (red line) and reach gross negative CO_2 emissions by the end of the century. F-gases: fluorinated gases. Credit: UK Royal Academy of Engineering (public domain).

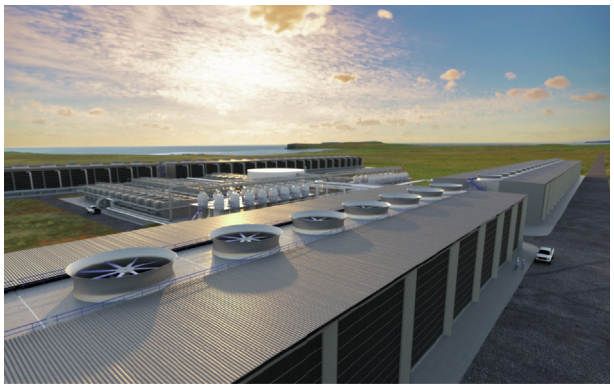

Fig. 2. An artist's illustration of a pilot DAC plant under construction in Squamish, BC, Canada, by Carbon Engineering, a Vancouver, BC, Canada-based decarbonization company that is working to scale up DAC technology into large commercial facilities around the world. Credit: Carbon Engineering (public domain).

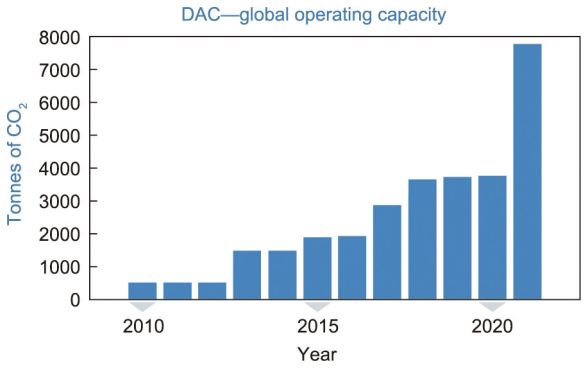

Fig. 3. The capacity of DAC facilities around the globe to directly filter CO_2 out of the atmosphere has increased considerably in recent years, but still pales in comparison to what may be needed to meet the climate change goals set out for the rest of the century. Credit: International Energy Agency (CC BY-SA 4.0).

begin operating in early 2023, one in Los Angeles and the other in Singapore [14]. "There are a lot of good ideas on the table, but we do not yet have a really clear idea of which will work best," said Sant.

The chemistry of how to capture CO_2 and sequester it in many compounds is well known, Sant said. "It is more of an engineering challenge right now than a scientific one," he said. To remove enough CO_2 from the atmosphere to slow global warming, one recent report estimated that the size of the global CDR industry will, by 2050, need to be as large as the current oil and gas industry [15]. Researchers and commercial ventures must figure out which approaches will be scalable to that level, as well as cost-effective and energy efficient. "There are only so many ways you can get carbon from the air, and then only so many things you can do with it once you have captured it, so a lot of these approaches are conceptually similar," said Sant. "What will differentiate them is how energy efficiently and cost effectively they are able to complete these steps and the scale they can achieve."

That is where funding for pilot and demonstration projects becomes key—a point underscored by policymakers at COP27 during the announcement of the Mission Innovation Launchpad. By building demonstration projects around the globe, each using different approaches and placed in different environments, the initiative aims to identify the most impactful technologies. "This will help us get the technology working and move it from the field to the market," said DOE Secretary Jennifer Granholm [16].

All this needs to happen quickly. "We cannot take 30 years to do this," said Brad Crabtree, DOE Assistant Secretary for Fossil Energy and Carbon Management. "We must compress the typical timeframe and that is why demonstration projects are so critical—we have to create market and investor confidence by showing that the technology works technically and, ultimately, commercially" [17]. To this end, 3.5 billion USD of the May 2022 US Bipartisan Infrastructure Law will fund four regional DAC hubs in the United States, with the sites for the hubs and exact technologies to be used yet to be selected [15]. At the same time, several large DAC plants funded by the private sector are in the works; in Texas, for instance, oil giant Occidental Petroleum is building what the company claims will be the largest carbon capture project yet [18].

As the number—and diversity—of CDR projects grows, experts also stress the need for establishing standards for comparing the different approaches [19]. To address this need, on 7 November 2022, the DOE announced a funding call for projects specifically related to CDR reporting and measurement, with money coming from the Bipartisan Infrastructure Law [20]. "One of the most important conversations in the carbon removal ecosystem today is around measurement, reporting, and verification," said Rubin. "When someone says their system is removing one tonne of CO_2 from the atmosphere and storing it, we need to be able to confirm that it is one tonne and how long it can be stored."

As new funding begins to flow into the field through both direct research support and tax credits for carbon removal, everyone from basic scientists to commercial ventures is seeing the pace of CDR development speed up. At the Pacific Northwest National Laboratory (Richland, WA, USA), research chemist Todd Schaef said there has been a spike in interest about his long-standing work on locking CO_2 away in basalt rock formations. "This was a little bit of a niche thing a decade ago and now it is really coming to the forefront. I get calls on at least a weekly basis from people who want to hear more about it," said Schaef. "The increased attention and funding are letting us move forward with projects that have been dormant for a decade."

In 2013, Schaef and colleagues began a field demonstration of their carbon storage technology, injecting 1000 tonnes of CO_2 into a basalt formation in Wallula, WA, USA [21]. Now, with nine years of data on the stability of the locked-away carbon, the team—awarded new DOE funding in early 2022—is collaborating with academic and industry partners on a new pilot site in central Minnesota [22]. Like the dozens of other pilot and demonstration projects now popping up around the world, the new facility aims to test the potential of its particular technology to play a part in helping to slow global warming. "There is not going to be one solution," Schaef said. "There is plenty of CO_2 in the atmosphere for us all to work on—this is going to take all hands on deck."

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