Where Can We Store Carbon Dioxide?

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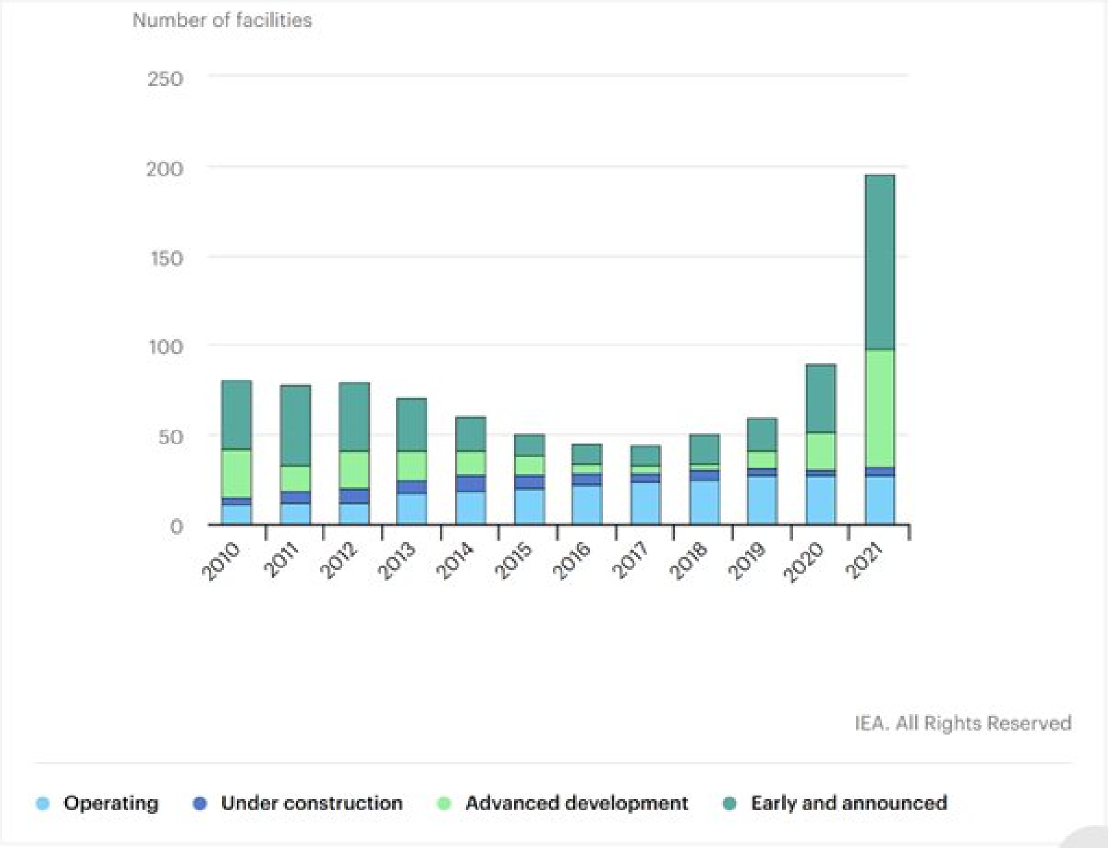
The concept of physically removing carbon dioxide (CO2) directly from the air has gained momentum in the midst of significant, sustained global focus on climate change. We see in Figure 1 that projects focused on carbon capture, utilisation and storage that are either in 'advanced development' or 'early and announced' phases jumped dramatically in 2021. Notably, the number of 'Operating' facilities has been fairly stable in recent years.

Figure 1: Global Pipeline of Commercial Carbon Capture, Utilisation and Storage Facilities Operating and in Development, 2010 to 2021



Source: International Energy Agency (IEA), Global pipeline of commercial, Carbon capture, utilisation and storage (CCUS) facilities operating and in development, 2010-2021, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-pipeline-of-commercial-ccus-facilities-operating-and-in-development-2010-2021

Historical performance is not an indication of future performance and any investments may go down in value

Eighteen plants are currently operational globally and are located in Canada, Europe and the United States. Two technology approaches are currently used to remove the CO_2 from the air1:

1. Solid 'Direct-Air-Capture' technology makes use of solid filters that chemically bind with CO_2. When the filters are heated, they release concentrated CO_2 that can then be used.

2. Liquid 'Direct-Air-Capture' technology pass air through chemical solutions which removes the CO_2 while returning the rest of the air to the environment.

The cost of removing CO_2 from the air depends on many factors, and the current research recognises that there are not large numbers of plants operating at massive scale. As more facilities are built and capacities for removal are increased, the true cost of removing carbon from the air will become more and more accurate.

But, the question then becomes, once the CO_2 is removed from the air—what do you do with it?

A company, Climeworks, is running the Orca device, the world's largest commercial direct air capture device. The machine is located roughly 20 miles outside of Reykjavik in Iceland.

Fans, powered by geothermal electricity, suck in air. Carbon Dioxide (CO_2) bonds with a sand-like filtering substance. Once heat is applied, the CO_2 is released and mixed with water by an Icelandic company called Carbfix2.

Carbfix has discovered that this CO_2 mix will react chemically with basalt and turn to rock in just 2 to 3 years, as opposed to the centuries that the mineralisation process was believed to take. The notable factor here is that this represents a permanent solution3.

The Orca machine can remove 4,000 metric tonnes of CO_2 annually. However, this quantity is only about three seconds of humanity's annual global emissions, which are closer to 40 billion metric tonnes4.

Clearly, the question is not whether it is possible to suck CO_2 out of the air, but rather whether it can be done at a scale that would have a meaningful impact on climate change. However, this is actually a classic question5:

- Humanity was likely saying something similar in 1980 about the world's first commercial wind farm, which consisted of 20 turbines and an output of 600,000 watts.
- Forty years later in 2020, the world's installed wind capacity was 1.23 million times larger, at 740 gigawatts.

If Orca's removal capacity was increased at the same rate, it would yield CO_2 removal capacity of 5 billion metric tonnes by around 2060.

LanzaTech traps carbon that would be emitted during industrial processes and uses bacteria to convert the waste gas into sustainable chemicals. Companies, like the Chinese steelmaker Shougang Group Co. add LanzaTech's technology to their manufacturing process6.

One process being utilised actually creates fuel, with the possibility to generate hundreds of billions of gallons per year. Acetogenic microbes are used in a fermentation process that can be set up to use the CO2 coming from 1) industrial waste gas 2) agricultural processes 3) solid waste 4) biomass, just to name a few potential sources. The principle is based on the fact that any liquid fuel must contain carbon—the microbes are able to take it from the air (CO2) and convert it to a chemical format that can be useful as fuel7.

In fact, early efforts to develop synthetic aviation fuels using air-captured CO2 and hydrogen have begun. In the Net Zero Emissions by 2050 Scenario, roughly one-third of aviation fuel demand is met with these synthetic fuels. Currently, the cost is too high—about five times the conventional options. As innovations drive costs down, these processes become more and more interesting8.

Conclusion: Carbon Capture, Utilisation and Storage Represents an Important Arrow in the Quiver to Combat Climate Change

2022 represents an interesting time in many technologies. Success and scalability, while not assured, is beginning to look more and more possible. Directly removing CO2 from the air will not be a panacea—we will still have to make progress on other fronts in the battle against climate change. Still, we believe it will represent an important component of the mix in getting the world to net zero by 2050.

1 Source: "Direct Air Capture: A Key Technology for Net Zero." IEA. April 2022.

2 Source: Wilson, Peter. "Is Carbon Capture Here?" The New York Times. 31 October 2021.

3 Source: Wilson, 2021.

4 Source: Wilson, 2021.

5 Source: Wilson, 2021.

6 Source: Ramkumar, Amrith. "Carbon-Transformation Start-up LanzaTech is Going Public in $2.2 Billion SPAC Deal." Wall Street Journal. 8 March 2022.

7 Source: https://www.energy.gov/sites/prod/files/2017/07/f35/BETO_2017WTE-Workshop_SeanSimpson-LanzaTech.pdf

8 Source: "Direct Air Capture: A Key Technology for Net Zero." IEA. April 2022.

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