Direct air capture (DAC)

HEADLINES

• IPCC pathways that limit global warming to 1.5°C make use of carbon dioxide removal (CDR) technologies to various extents. Direct Air Capture (DAC) is one of these technologies.

• These technologies will have to be deployed at a scale sufficient to offset non-mitigated CO\textsubscript{2} emissions and further remove CO\textsubscript{2} from the air; for this reason, DAC alone will not be able to address the climate change issue.

• In line with the long term vision of achieving net-zero greenhouse gas emissions by 2050, CDR technologies are expected to support generating negative emissions.

• Cost reductions for DAC are expected by 2025-2030; hence our view is that DAC could roll out beyond that time frame.

• DAC as a part of CDR could make a notable impact on CO\textsubscript{2} removal, once commercially deployed at scale, only around 2050.
THE DEBATE

The idea of capturing carbon dioxide (CO\textsubscript{2}) directly from air has been pitched within climate change circles for well over a decade. In 2017, the ‘direct air capture’ technology, or DAC, was put to test in the real world with the first commercial plant launched in Switzerland (Figure 1). Will DAC be an important tool in our portfolio of technologies to support ongoing efforts to achieve our vision for a climate-neutral economy by mid-century?

THE ARGUMENTS

Capture... anywhere
Enabling the direct extraction of CO\textsubscript{2} from the atmosphere is a main benefit put forward. Land use and hardware distribution are commonly raised issues, but research suggests that DAC units have minimal land requirements compared to other Negative Emissions Technologies (NETs), such as for example Bioenergy with Carbon Capture and Storage (BECCS).\footnote{As a comparison, land use for BECCS – a highly land intensive technology – ranges from 1,000 to 17,000 m\textsuperscript{2} per tonne of carbon equivalent (C\textsubscript{eq}) per year, depending on feedstock type.}

On the other hand, a meaningful contribution to CO\textsubscript{2} emissions reduction requires carbon-neutral energy and/or heat to operate DAC. This need may limit the selection of possible locations to those where these resources are available [1].

Requirement for resources
Depending on the separation technology used DAC may need between 0.32 and 4.73 MWh per tonne of CO\textsubscript{2} [2] removed from air, but there is a ‘fundamental disagreement on the actual amount of energy required’ [3]. For a rough comparison, the capture of 90\% of the CO\textsubscript{2} generated in a natural gas fired power-plant would require 0.38 MWh/t CO\textsubscript{2} [4]. DAC also requires considerable water input\footnote{To remove 1 t of CO\textsubscript{2}, DAC (e.g. amines) requires approximately 90 m\textsuperscript{3} of water [17,18].} – to offset just the non-mitigated CO\textsubscript{2} emissions DAC\footnote{Assuming current amine technology as in [17].} would require nearly as much water as used in a country the size of Italy [4].

The price tag
In 2011, the cost of capturing a tonne of CO\textsubscript{2} from air was estimated at around €440 ($600) [5]. On the same year, a study estimated costs even around €1,000 per tonne CO\textsubscript{2}. In 2018, cost estimations reduced to between €80 ($94) and €200 ($232) [6].\footnote{This range reflects differences in design choices which could further reduce costs in the future.} This range reflects differences in design choices which could further reduce costs in the future.

1 As a comparison, land use for BECCS – a highly land intensive technology – ranges from 1,000 to 17,000 m\textsuperscript{2} per tonne of carbon equivalent (C\textsubscript{eq}) per year, depending on feedstock type.
2 To remove 1 t of CO\textsubscript{2}, DAC (e.g. amines) requires approximately 90 m\textsuperscript{3} of water [17,18].
3 Assuming current amine technology as in [17].
4 Based on emission reductions required for limiting temperature increase to 1.5\(^\circ\)C, as outlined in the European Commission’s long-term strategic vision (scenario 1.5TECH) [13] and on water use data from [19] referring to all activities.
5 All values adjusted for inflation and assuming $1=€0.86272 (source: https://www.oanda.com/currency/converter/, accessed October 2018).
Location, location, location

When approaching the lower end of cost, DAC starts to look viable in a climate-neutral world. Yet, the broad cost range indicates the current uncertainty associated with DAC. Amongst others, regionally dependent factors (such as the type and cost of energy needed to power the process, CO₂ volumes and the availability of a CO₂ pipeline network and storage locations) will affect the costs and thus the viability of the process. In Europe, a CO₂ capture cost as low as €80/t ($94) and a natural gas price of €3/GJ (or 3.5 $/GJ) as assumed by Keith et al. [6] are hardly realistic.

What about emissions?

Whereas the biggest chunk of emissions comes from the energy sector, emissions are not only associated with power generation. In this context, DAC can support decarbonisation regardless of the emissions source. To achieve CO₂ emissions reduction, low-cost and low-carbon energy will be required to satisfy the high power demand associated with DAC operation. Still, specific trade-offs will not be avoided – using wind energy to power the DAC process to remove the emissions associated with a typical cement plant would require installing turbines on a land area almost equivalent to the City of Brussels. Pursuing DAC could become worthwhile after carbon capture and storage is applied to any remaining point sources [1].

Place and space

The number of DAC plants to be built per year is limited primarily from a cost perspective. To achieve major CO₂ emissions reduction and toward net-zero, it will need to be coupled with CO₂ transport and storage. Direct air capture is modular and developers claim it could be scaled up rapidly. Yet, it is uncertain whether DAC can be scaled up quickly enough and sufficiently to make an impact on CO₂ levels in the atmosphere in the medium term [5,7].

Going in cycles

As the planet moves towards a circular economy, DAC could go hand in hand with opportunities to utilize the captured CO₂. These include, for example, longer term approaches to CO₂ storage such as mineral carbonation or short term ones like fuel synthesis [8]. In industries without proximity to other CO₂ sources, DAC could cut down CO₂ transport costs even if these are minimal compared to the costs of CO₂ capture (~70-80% of the total [9]). DAC enhances the argument for processes using the captured CO₂ to have a climate change mitigation potential by creating a closed carbon loop. Nevertheless, it will need to be powered with clean energy and the captured CO₂ to be permanently stored. The Scientific Advice Mechanism High Level Group (SAM HLG), considered DAC for short-lived, CO₂-based products such as fuels, capturing of CO₂ from the air [10]. In this case, DAC would be necessary to achieve carbon neutrality provided that it is powered with renewable energy. However, the European Academies’ Science Advisory Council (EASAC) concludes that maximising mitigation with carbon capture and permanently storing CO₂ will reduce the future need to remove CO₂ from the atmosphere [11].

MARKET AND PROSPECTS

Seven leading commercial DAC system developers [12] and many companies are already demonstrating the technology on both sides of the Atlantic. Their business models include generating a revenue from the captured CO₂ for use in industries such as oil and gas, fuel production, materials, food and beverages but also in carbon markets. Climeworks for example, is offering CO₂ removal credits in an effort to boost funding and expand its carbon capture technology. As such, the perspective business case of DAC companies ultimately depends on the price of the CO₂ traded.⁶ DAC cost should drop by at least an order of magnitude with respect to its value today for this scheme to become lucrative. In Europe, Climeworks is the only one running a commercial plant in Zurich, Switzerland, and a pilot plant in Iceland. Climeworks’ commercial plant is selling its CO₂ to greenhouses while the Iceland pilot plant is the only one which, after capturing an annual 50 tonnes of CO₂, buries it in basalt rock. Climeworks, which operates a plant currently at a cost of €440, hopes to get this down to €90 per tonne CO₂ by 2025 or 2030.⁷ With carbon markets being the main funding instrument, DAC cost, even on the low end, would break even to the projected European Emission Allowance (EU) cost after 2045 [13].

RESEARCH AND INNOVATION

The EU is already funding DAC through the Horizon 2020 research project STORE&GO. In July 2018, another Direct Air Capture plant was launched in Troia, Apulia (Italy), within this project. Importantly, this project will also assess the economic and business aspects and market-uptake potential of the technology.

Research is ongoing to tackle issues common to conventional carbon capture such as high energy requirements, low efficiencies and high
cost. However, the challenge associated with the permanent storage of CO₂ remains an issue [14]. Available storage capacity or public perception among other issues underline that these elements will require serious consideration.

According to the IPCC, ‘avoiding overshoot and reliance on future large-scale deployment of carbon dioxide removal (CDR) can only be achieved if global CO₂ emissions start to decline well before 2030’ [15]. This is a clear message that timely action is needed for meeting our decarbonisation ambitions. If not, CDR technologies will be an urgent solution. However, DAC is only one of the CDR technologies that can be considered. Given the technology’s early stage of development and limited existing demonstrations, DAC’s potential impact can be positioned in the longer term. Compatibly with the EU’s long-term strategic vision for a prosperous, modern, competitive and climate neutral economy [16], we view that DAC could be impactful in compensating for non-mitigated CO₂ emissions in the long run. DAC is an interesting technology if viewed as a tool that could potentially fill gaps of current technologies and not as a stand-alone solution.

REFERENCES


Contacts: Zoi.KAPETAKI@ec.europa.eu