Direct Air Capture

Challenges and Opportunities

About LAVAUX

We are a leading strategy, operations consulting and organizational transformation firm.

At the heart of everything we do is our unrelenting drive to peek into and make sense of the future.

We are strategists, management consultants and advisors — inspired by transforming clients' businesses so that they can reach escape velocity.

To date, the carbon emissions embedded in the fossil fuel reserves exceed 3,200Gt of CO_2, that is roughly eight times the available carbon budget.
Under the NZE stringent goals, in 2050 the world will still be producing 25 MMbpd of oil, 920bcm of gas (of which 512 bcm abated with CCUS), and 500 MMtonnes of coal (81% abated with CCUS).

If emissions do not start declining in the next decade, the point of carbon neutrality would need to be reached at least two decades earlier to remain within the same carbon budget.

Direct Air Capture and Storage (DACS) is a technology that has been attracting a lot of debate lately in the energy transition space. Many are wondering whether DACS has a future in the NZE scenario, given the techno-economic challenges it faces.

In this briefing note, we evaluate the magnitude of these challenges objectively and formulate some guidance for this technology.

DACS in 2050 NZE.

Let's start with the DACS future goals.
According to the IEA NZE scenario, DACS is expected to capture and store around **1Gt by 2050**, which is approximately 1/6th – to 1/7th of the amount captured and stored via CCUS (in 2050).
In the EU for instance, DACS is set to play a prominent role in 2050 with over **170Mt of CO2** captured, as per the Feb. 6, 2024 CCS Directive from The European Parliament.

Are these targets realistic?

Capturing atmospheric carbon is more energy intensive than capturing carbon from a fixed-point source. As of 2024, DAC costs vary from $400/tonne to $1,000/tonne of CO2 captured. For the DAC to scale in a meaningful manner, we estimate that the **capital costs need to reach $100-$150 per tonne of CO2**. Let's look at the techno-economic requirements to achieve these targets.

<u>Energy economics</u>

We know that the current DACS processes require ~2,000 KWh per tonne of CO2 captured.

World: If we were to extrapolate these numbers to year 2050, to capture 1Gt of CO2 would require 2,000 TWh which amounts to ~8% of current electricity demand globally. That's a staggering amount, but the good news is that we expect DACS to make significant progress on energy efficiency front and improve in the years to come.

The EU: If we were to carry out the same set of calculations for the EU, DACS would require 340 TWh to capture 170 Mt of CO2. To put it into perspective, this amount of electricity is equivalent to the demand of Australia, Singapore, and then some, in 2023. Again, a steep challenge.

Thermodynamics (Fig.1) dictates that <u>**DACS will stay energy intensive**</u>. Canada's Carbon Engineering has an energetic requirement equivalent to either 8.81GJ of natural gas or 5.25 GJ of natural gas coupled with 366 kWh of electricity.

Elsewhere, the capital cost of constructing the Climeworks' 4,000 tonne DAC system, is estimated to be around $800/tonne of CO2.

<u>Technical challenges</u>

The main technical challenge that DACS faces is the low concentration of CO2 in the atmosphere (0.04%).

Because of this low CO2 concentration, the technology requires low-cost air contactors that minimise pressure drop and allow large air volumes through the contractor.

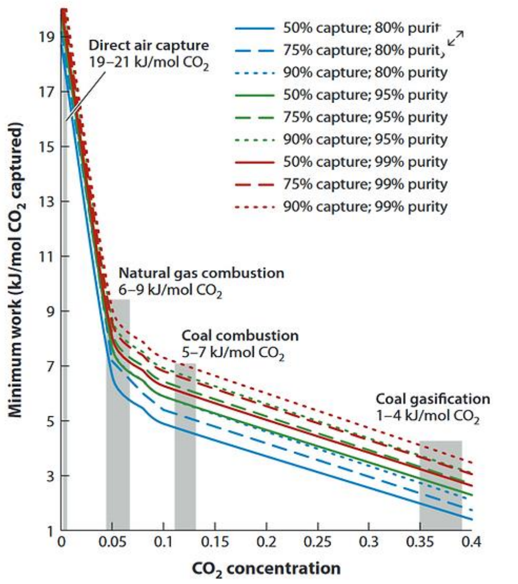

Fig. 1 Comparison of minimum work for CO2 capture for various capture percentages and purity percentages from the atmosphere to the concentrated fuel gas of coal gasification

Also, the CO_2 binding energy must be high enough to achieve a good uptake capacity, but not too high that the release of the CO_2 has unacceptably high energy (heat) requirements. And finally, the expected lifetime of the sorbents plays a key role in minimising the lifecycle capital costs.

The United States has established several policies and programmes to support DAC, including the 45Q tax credit and the California Low Carbon Fuels Standard credit. The Inflation Reduction Act (IRA) announced in August 2022 expands and extends the 45Q tax credit up to USD 180/t CO_2 permanently stored. The Infrastructure Investment and Jobs Act (signed into law in November 2021) includes USD 3.5 billion in funding to establish 4 large-scale DAC hubs, and related transport and storage infrastructure (the first funding opportunity announcement under this programme closed in March 2023).

Around 35 DAC projects have been announced in the USA since the IRA, including project Bison (to capture 5 $MtCO_2$/year by 2030) and 30 DAC plants in King Ranch, Texas (each up to 1 $MtCO_2$/year each, up to 15 of which could be operational by 2030).

Conclusion

DACS is an emerging technology with **an important role to play in the net-zero emissions** world but faces technical and economic challenges. We are confident that given the continuing support in the EU and the US (but also in other jurisdictions), the technology will make progress on both fronts to bring **development costs close to $100/tonne of CO2** captured where projects start to make sense commercially.

LAVAUX

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