DIRECT AIR CARBON CAPTURE AND SEQUESTRATION (CCS)

The case for DIRECT AIR CAPTURE

The term direct air capture (DAC) refers to a range of technologies that use chemicals to capture and concentrate carbon dioxide from the ambient air. Although most DAC technology is being developed as a carbon-neutral fossil-fuel replacement, DAC systems have the potential to generate net-negative emissions when coupled with carbon sequestration systems that store CO2 geologically or in non-degradeable commercial products. This fact sheet explores the opportunities and challenges surrounding direct air capture and sequestration, or "Direct Air CCS."

ABOUT US

The Center for Carbon Removal is a non-profit initiative of the Berkeley Energy & Climate Institute. We are dedicated to curtailing climate change by igniting action to develop and implement strategies for removing carbon dioxide from the atmosphere by:

- Conducting research and analysis to highlight opportunities and address challenges surrounding carbon removal solutions.
- Curating a comprehensive online hub for high-quality information and discussion about carbon removal.
- Hosting events that engage public, private, and civil sector organizations to accelerate the development of carbon removal solutions.
THE TECHNOLOGY

Direct air capture (DAC) systems can be thought of as artificial trees. Where trees use photosynthesis to extract CO₂ from the air, DAC systems rely on chemicals capable of selectively binding with CO₂, but not other chemicals in the air. Once the chemicals become saturated with CO₂, energy is added to the DAC system (in the form of heat, humidity, pressure, etc.) to release the CO₂ in concentrated form, and the chemicals are regenerated to repeat the process.

LEADERS

DAC is not an entirely new technology. Similar systems have been installed in submarines and in space applications for decades (it would be impossible to breathe in these closed environments without DAC). That said, large-scale DAC systems used to fight climate change are only beginning to emerge. There are currently no commercial-scale deployments of DAC systems for carbon management purposes. Today, there are six leading commercial DAC system development efforts, along with one academic center pursuing DAC research, though none of these efforts are focused on sequestration today:

- **Carbon Engineering** is pursuing a liquid potassium hydroxide based system, which they will use to enable production of ultra-low carbon fuels. They have a pilot plant in Squamish, BC set for an October 2015 launch date.
- **Skytree** is a direct air capture company that focuses on the CO₂ capture for the consumer market, producing small scale prototypes that source CO₂ for aquariums, greenhouses, local air purification, and water treatment.
- **Global Thermostat** is pursuing a DAC technology based on proprietary amine sorbents with a temperature swing for regeneration. Global Thermostat has partnered with NRG Energy and Linde, and has a pilot plant up and running in Menlo Park, CA.
- **Infinitree** is using a humidity swing process for concentrating CO₂. They are targeting the greenhouse market for initial customers. This technology is based on the DAC system developed by now-bankrupt Kilimanjaro Energy.
- **ASU Center For Negative Emissions** at Arizona is an academic group headed by professor Klaus Lackner and is developing a DAC technology based on a humidity swing process.
- **Climeworks** is a direct air capture company that focuses on the CO₂ capture for the consumer market, producing small scale prototypes that source CO₂ for aquariums, greenhouses, local air purification, and water treatment.

**Center for Negative Carbon Emissions at ASU** is an academic group headed by professor Klaus Lackner and is developing a DAC technology based on a humidity swing process.
The groups working on direct air capture technology today use the captured CO₂ for carbon-neutral “recycling.” Yet, increased policy incentives can help DAC to be used for carbon “removal” or sequestration purposes. We explore the differences between the two business models below.

**RECYCLING**

Without strong carbon prices, DAC systems are likely to be used for recycling CO₂ into fuels and chemicals (as these are the highest value markets today and provide crucial near-term revenue streams for DAC technology developers).

**SEQUESTRATION**

With increased incentives for carbon sequestration over time, DAC can be deployed as a carbon removal solution, where the business case for DAC is based on regulatory incentives for carbon sequestration.

**USES & STORAGE**

- Enhanced Oil Recovery
- Fuels
- Chemicals
- Greenhouse CO₂
- Beverage production
- Geologic Storage
- Non-degradable, carbon-negative materials (e.g. plastics or cements)

**DAC IN COMPARISON TO TRADITIONAL CCS**

**ADVANTAGES**

DAC systems can be sited anywhere, meaning that they can eliminate the sometimes costly CO₂ transportation step associated with other carbon removal systems (and with traditional carbon capture and sequestration systems on power plants). In addition, DAC can be scaled easily and has a relatively small land footprint in comparison to other carbon removal approaches.

**ENERGY**

Because the concentration of CO₂ in ambient air is relatively low (0.04% as compared to concentrations from point source capture), direct air capture is a fairly energy intensive process. Theoretically, to get a 100% pure CO₂ stream at the maximum possible efficiency, the American Physical Society report cites that it takes approximately 497 kJ of energy to generate 1 kg of compressed CO₂. Scaling up, to get to the billion ton scale of CO₂ capture viewed by many experts as climatically significant, DAC systems would require about 10 GW of power, equal to that produced by about 20 average size coal power plants. Energy requirements decrease with more dilute concentrations of CO₂.

**COSTS**

Because direct air capture technology is still developing and improving, no one really knows how much direct air capture will cost at commercial scale. A National Research Council study finds that direct air capture will cost a minimum of $60/t CO₂ with additional costs for storage. First of a kind prototypes, however, cost several hundred dollars per ton of concentrated CO₂ today. Since the costs of DAC technology are heavily dependent on manufacturing costs, these costs are likely to come down significantly if DAC is manufactured modularly.
DIRECT AIR CAPTURE IN POLICY

Currently, there is minimal policy support from the federal government to support air capture technology. In terms of direct funding, the U.S. Department of Energy currently has a $3 million solicitation for air capture technology and the FY 2016 federal budget has a $250,000 carve out to aid in the development and commercialization of direct air capture technology. However, beyond direct funding, there are no policies explicitly catered to incentivize the development and adoption of direct air capture adoption of direct air capture. Further, current regulations on CO₂ generally often do not include protocols that allow direct air capture count as compliance.

EXTERNAL RESOURCES

four direct air capture “must reads”


CONTACT US

www.centerforcarbonremoval.org
info@centerforcarbonremoval.org
@CarbonRemoval
(510) 664 - 7153