Current status and pillars of direct air capture technologies

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Climate change calls for adaptation of negative emission technologies such as direct air capture (DAC) of carbon dioxide (CO_2) to lower the global warming impacts of greenhouse gases.

DAC can help with hard-to-avoid carbon emissions from distributed sources (transportation, wildfires) and from natural gas processing, the production of cement, iron, steel, ammonia, and urea, biofuel use, and more, helping to offset the nearly 1.9 billion tons of industrial CO2 emissions per year that cannot be feasibly avoided using production technologies.[1]

Recently, elevated global interests to the DAC technologies prompted implementation of new tax credits and new policies worldwide that motivated the existing DAC companies and prompted the startup boom. There are presently 19 DAC plants operating worldwide, capturing more than 0.01 Mt CO_2/year. DAC active plants capturing in average 10,000 tons of CO_2 annually are still in their infancy and are expensive.

DAC technologies still need to improve in three areas: 1) Contactor, 2) Sorbent, and 3) Regeneration to drive down the costs. Technology-based economic development in all three areas are required to achieve <\$100/ton of CO_2 which makes DAC economically viable. Current DAC cost is about 2–6 times higher than the desired cost and depends highly on the source of energy used.

The implementation of DAC faces two major technical challenges: (1) energy and (2) materials. Current CO_2 emissions reach nearly 32.6 gigatons/year. With the assumption that only 25% of total CO_2 emissions would be captured, implementing existing liquid and solid sorbent DAC systems would require 10%–20% and 30%–50% of the total global energy supply, respectively. This includes the energy needed to produce sorbent materials and sorbent regeneration. High energy demand could raise the final cost of carbon capture; therefore, inexpensive and low-carbon energy sources are vital. The current goal for DAC is to keep the cost at \$100/tCO_2.[3]

Sorbent material production must also ramp up to meet the demand for DAC scaling. For example, to capture 25% of the total CO_2 emissions per year, sorbents must be produced on the gigaton scale, requiring 20 to 30 times more NaOH, NH_3, and ethanol than is currently produced. Similarly, steel and other construction materials have to scale up, too. The sustainability of DAC will depend on the use of affordable, low-carbon, and low-power capture technologies and stable and selective sorbents with a shortage-free supply chain.

In this presentation, I will talk about the current status of commercial DAC technologies and elucidate the five pillars of technology including capture technologies, their energy demand, final costs, environmental impacts, and political support. I will explain processing steps for liquid and solid carbon capture technologies and indicate their specific energy requirements. DAC capital and operational cost based on plant power energy sources, land and water needs of DAC will be discussed in detail. At 0.01 Mt CO_2/year capture capacity, DAC alone faces a challenge to meet the rates of carbon capture described in the goals of the Paris Agreement with 1.5–2°C of global warming. However, DAC may partially help to offset difficult to avoid annual emissions from concrete (~8%), transportation (~24%), iron-steel industry (~11%), and wildfires (~0.8%). [2]

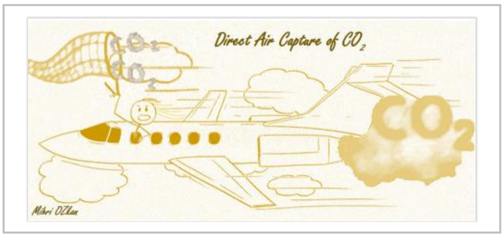

Figure 1. Cartoon expression of DAC.
Prepared by Mihri Ozkan.[1]

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