THE GNCS FACTSHEETS

Air Capture

Stabilizing carbon dioxide (CO_2) emissions at a level that would "prevent dangerous anthropogenic interference with the climate system" will require net emissions worldwide to decline towards zero.[1] Given the substantial reductions needed and the inertia of transforming global energy sources, technologies to remove CO_2 from the air will likely be necessary. While CO_2 removal occurs naturally in the surface ocean and during photosynthesis, its direct removal from ambient air is also achievable through the industrial process of air capture. This is appealing because it allows CO_2 reductions to be achieved anywhere (*e.g.* near storage sites) and can be built to any scale. Unlike carbon capture and storage (CCS) from large power plants and industrial emitters, it would allow for the reduction of the absolute level of CO_2 rather than just its rate of increase. This opens up the prospect of actively managing global atmospheric CO_2 levels. Air capture technology is in early stages of development but could be a powerful and, ultimately, necessary tool to combat climate change. However, as its deployment at a level required to have any meaningful impact will be unavoidably slow, it cannot act as a backstop against an abrupt climate emergency.[2] Its development is hindered by current costs and energy inefficiencies. Both government investment and a price on carbon will be critical to overcoming these obstacles.

Status of the Technology

The technology to capture CO_2 from the atmosphere and immobilize it in geological structures has been successfully demonstrated.[3] However, it has not been proven at scale, or cost effectively. While various methods of air capture exist, the essential premise of the technology is a system that uses a sorbent material to selectively capture CO_2 from ambient air. Since CO_2 quickly mixes in the atmosphere and is essentially evenly distributed around the globe, air capture facilities can be installed anywhere, *e.g.* near sequestration sites.

Three promising air capture designs, with various advantages and disadvantages, are the spray hanger, the solar scrubber, and the air collector:[4]

1. The *spray hanger* uses a system whereby air blown through a scrubber is showered with a sodium hydroxide solution that reacts with CO_2 to form sodium carbonate. The sodium carbonate solution is then heated to 900°C in a kiln to separate the CO_2 for storage and the sodium hydroxide for reuse. This process, while well tested, is extremely energy intensive, although its developers suggest that the energy requirements could be halved and costs could be in the range of $100 per ton.[5] Carbon Engineering, an independent Canadian company, raised $6 million for a three-year R&D phase, with plans to eventually develop a fully integrated industrial pilot plant that could supply at least 10,000 tons of CO_2 per year.[6]

2. The *solar scrubber* method is an adapted version of concentrated solar power, utilizing solar energy to heat up tubes full of air and calcium oxide pellets. At 400°C the two react and form calcium carbonate. By increasing the temperature to 800°C, the CO_2 is converted to a stream of pure gas ready for sequestration and the calcium carbonate converts back to calcium oxide. A disadvantage is the intermittency of the sunlight needed to operate (although consistent and continuous operation is not as essential as in, say, electricity generation) and pricing models are undeveloped.[7]

3. The *air collector* uses an ion exchange resin (a polymer infused with sodium hydroxide) which binds with CO_2 to form sodium bicarbonate. The large surface of the resin sheets expedites the reaction and the CO_2 can easily be stripped off the resin by adding moisture. These

[1] Barrett, S. (2010). "Climate Treaties and Approaching Catastrophes." Preliminary draft. New York: Columbia University.
[2] Socolow, R. *et. al.* (2011). "Direct Air Capture of CO_2 with Chemicals." A Technology Assessment for the APS Panel on Public Affairs. p. i.
[3] Earth Institute. (2007). "First Successful Demonstration of Carbon Dioxide Air Capture Technology Achieved." *Earth Institute News*. New York: The Earth Institute, Columbia University.
[4] Kunzig, R. and Broecker, W. (2009). "Can Technology Clear the Air?" *New Scientist*. 12 January 2009.
[5] Kunzig and Broecker (2009).
[6] See Carbon Engineering at: http://www.carbonengineering.com/.
[7] Kunzig and Broecker (2009).

air scrubbers only need temperatures of 40°C but a lack of investment in the technology has been a limiting factor for commercialization.[8] Kilimanjaro Energy, formerly Global Research Technologies, assert that a one-ton per day unit could achieve CO_2 capture at $125 per ton and potentially lower costs as the technology matures.[9]

Abatement Potential

Air capture technology can potentially be scaled up to any level.[10] Its limitations are costs, which remain high as the technology is still under development, and energy efficiency. Air capture requires energy sources throughout the process, including energy to move the air, manufacture the absorbing solutions and solids as well as to sequester and transport the CO_2 output stream.[11] These additional processes may result in additional CO_2 emissions, which reduce the efficiency and therefore the benefits of air capture. Evaluation of air capture performance is, like the technology, in its early stages but it is estimated that it takes ~0.5 joules of energy to capture the emissions generated in producing 1 joule of fossil fuel energy.[12] The energy required could, of course, be provided by renewable sources, though the verdict is out on whether it is more beneficial to do so in the near term rather than displace fossil fuel power plants.[13]

An inefficiency relative to industrial CCS is that the concentration of CO_2 in the atmospheric air is approximately 0.04% (about 390 parts per million), whereas concentrations in combustion streams range from 5-15%.[14] However, several researchers and startup companies are challenging the notion that this low concentration means carbon capture from ambient air requires too much energy to be practical or cost effective.

Air capture technology is also the only way to capture non-stationary CO_2 emissions, *e.g.* from road vehicles and airplanes. The transportation sector represents around 14% of global CO_2 emissions (27% of total US emissions in 2008) and is projected to double by 2050.[15]

[8] Ibid.
[9] See Kilimanjaro Energy at: http://www.kilimanjaroenergy.com/.
[10] Barrett (2010).
[11] Keith, D. *et al.* (2005). “Climate Strategy with CO_2 Capture From the Air.” *Climatic Change.*
[12] The minimum energy required is about 1.6 GJ/tC. Keith *et al.* (2005).
[13] Socolow *et. al.* (2011), p. iii.
[14] Keith *et al.* (2005).
[15] IEA. (2009). “Transport, Energy and CO_2: Moving toward Sustainability”. Paris: International Energy Agency.

A shipping container size unit, like that being developed by Kilimanjaro Energy, could capture 1 ton of CO_2 per day, meaning 10 million devices would be needed to collect 3.6 billion tons of CO_2, or 12% of total annual emissions. Some 100 million units would be required to actually lower CO_2 concentrations. Air capture relies on the long-term storage of CO_2, which is a challenge in itself (see GNCS factsheet on carbon storage).

Abatement Costs

Air capture technology has yet to be demonstrated at a reasonable cost. A group of experts estimated current costs at $600/t$CO_2$ abated, but pioneers hope to bring this down to $100/t$CO_2$.[16] Ultimately, the unique aspect of air capture is that it provides abatement across all economic sectors at a fixed marginal cost.

In the absence of a universal price on carbon, developers have sought other commercial opportunities for early stage development. These include supplying captured CO_2 to fruit and vegetable growers, who frequently pay upwards of $300/t$CO_2$ to enrich greenhouses, and to oil companies for enhanced oil recovery. However, these small markets could be easily saturated and will not sustain the commercial growth of the technology.

Policy for the Future

Despite the potential of air capture to reduce CO_2 and eventually act as a backstop technology against climate change, investment has been minimal and thus the technology is still in its infancy. Only recently did the US Department of Energy include “CO_2 capture from the atmosphere” in $2.4 billion research funding for CCS, marking the first time air capture has been included in any government program.[17] The research community working on the subject remains small and air capture has not yet been discussed in international forums.

In the future, air capture could allow humanity to actively manage greenhouse gas levels in the atmosphere. This would require new governance arrangements and/or institutions to manage its deployment.

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Further resources are available at **www.theGNCS.org**

[16] Socolow *et al.* (2005); Lackner (WHAT?)
[17] Chichilnisky, G. *et. al.* “How air capture could help to promote a Copenhagen solution”. *Nature*. June 2009.