Direct Air Capture: The Dire Climate Consequences of Capturing Carbon From the Atmosphere

Of all the technologies proposed to combat the climate crisis, perhaps none is as intuitively appealing as direct air capture (DAC). The premise of DAC (sometimes called "open air capture") is simple: Machinery would capture carbon dioxide (CO_2) from the atmosphere, then compress, transport, and store it in underground reservoirs.

But despite decades of hype, DAC still plays no role in carbon removal. The recently announced proposal to build a facility in Texas — an $811 million project that would be the largest direct air capture facility in the world — gives a sense of the scale of the problem. The plant owners promise to capture "up to" 500,000 metric tons per year, one hundredth of one percent of U.S. CO_2 emissions.[1]

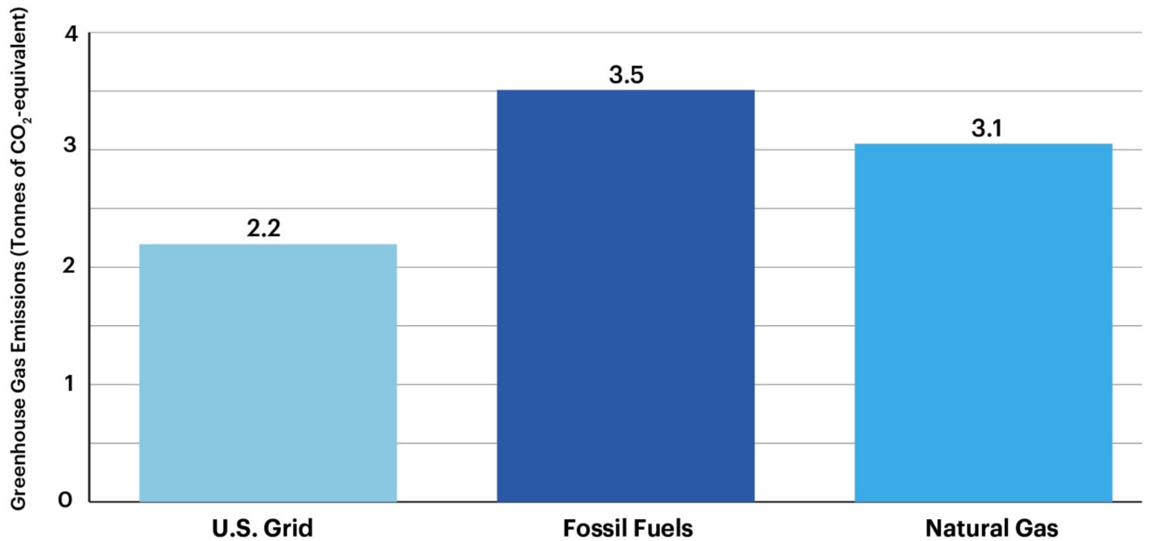
Direct air capture is prohibitively expensive and energy intensive; if it were ever to be successfully deployed, it would likely create more greenhouse gas emissions than it would capture. The promise of capturing CO_2 directly from the atmosphere not only delays the transition away from fossil fuels, it also powers and subsidizes increasing fossil fuel extraction and use. Replacing fossil fuels with renewables — rather than using fossil fuels to pull carbon out of the atmosphere — is a proven and significantly more cost-effective method of addressing climate change.

Direct Air Capture Cannot Be Scaled

Direct air capture is materially and energy intensive because of the low concentration of CO_2 in the air.[2] Building the technology that could pull carbon from the atmosphere would require considerable physical space — a DAC plant capable of capturing just one megaton of CO_2 per year takes up to 409,000 square feet of space.[3] More importantly, direct air capture also consumes large quantities of water and electricity.[4] Food & Water Watch (FWW) found that if all electricity generated in the United States were used to power DAC, it would capture only one-quarter of the carbon emissions generated by the country each year (see methodology section).

Generating this electricity would create more greenhouse gas emissions than the CO_2 captured at DAC facilities. According to calculations by FWW, capturing 1 ton of CO_2 from the atmosphere using electricity from fossil fuels would create greenhouse gas emissions equivalent to 3.5 tons of CO_2. Using enough electricity from the U.S. grid to capture 1 ton of CO_2 from the air would create 2.2 tons of CO_2-equivalent emissions.

FIG. 1: Emissions to Capture 1 Tonne of Carbon from the Atmosphere
BY ELECTRICITY SOURCE



SOURCE: Food & Water Watch analysis (see Methodology)

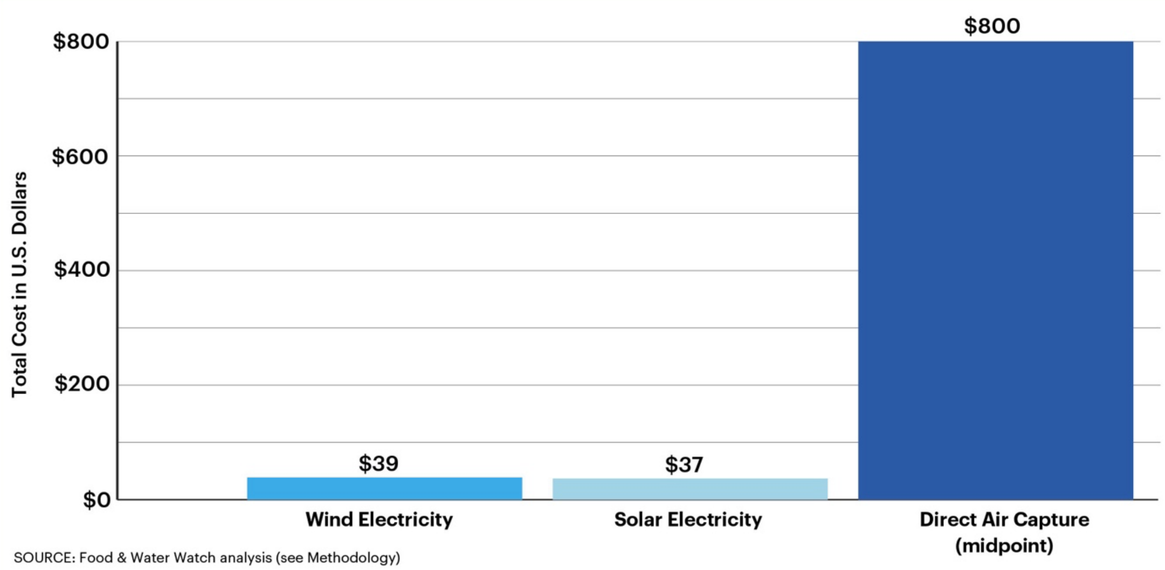
While using electricity from renewable energy could theoretically avoid this problem, that would involve building out a massive amount of clean energy capacity just to support the continuing extraction and combustion of fossil fuels. It is far more advantageous to simply shift our grid from fossil fuels to renewable energy. For instance, FWW found that replacing natural gas with renewables in the electrical grid avoids three times the amount of greenhouse gas emissions that could be captured by a DAC facility powered by renewable electricity. Additionally, the high temperature requirements of some common CO_2 capture systems make the process unable to use electricity (potentially generated from renewable sources) without additional technological progress.[5]

Direct Air Capture Is Absurdly Expensive

There is no way to turn a profit from capturing carbon pollution. To create an incentive for direct air capture, these facilities are eligible for a federal tax credit called 45Q. It is worth up to $180 per metric ton for captured CO_2 that is sequestered underground, and $130 per metric ton for CO_2 used for enhanced oil recovery (EOR).[6] However, several cost estimates put the costs of direct air capture systems at $600 to $1,000 per ton of CO_2 captured. This suggests that to make the technology work, DAC will require more subsidies on top of the exorbitant 45Q tax credits.[7]

To illustrate the scale of the costs involved, consider that capturing one-quarter of annual U.S. CO_2 emissions from the atmosphere would cost between $700 billion and $1.2 trillion per year[8] — and would be worth between $153 billion and $212 billion per year in 45Q tax credits.[9]

FIG. 2: Cost to Reduce 1 Tonne of CO_2-equivalent
BY TECHNOLOGY



SOURCE: Food & Water Watch analysis (see Methodology)

In comparison, FWW found that reducing the same quantity of greenhouse gas emissions with direct investments in wind and solar projects would cost $45 billion, roughly one-fifteenth the cost of using DAC. Even assuming that 45Q subsidies are sufficient to finance DAC, there are significantly better technologies to subsidize. If 45Q credits were dedicated to making new renewable projects cheaper than operating the cheapest gas plant, the subsidies would be nearly ten times as effective at reducing greenhouse emissions, even ignoring the electricity demands of DAC.

All Carbon Capture Systems Rely on Toxic Solvents

In addition to being an ineffective means of reducing carbon pollution, DAC would create substantial environmental threats. The two most "promising" direct air capture solvent technologies are based on either aqueous hydroxide solutions (NaOH, KOH, etc.) or amine-modified solutions (such as monoethanolamine, or MEA).[10] Industrial production of NaOH is very energy intensive and would massively increase production of chlorine gas, far exceeding utilization capacity.

Capturing one-quarter of U.S. CO_2 emissions would produce 245.5 million metric tons of chlorine gas, 3.2 times the current global use of chlorine gas.[11] Since current chlorine demand exceeds production, chlorine gas is used rather than disposed; there is not currently a large-scale disposal system for chlorine gas.[12] Chlorine gas is highly toxic and corrosive, with both acute and long-term negative human health effects.[13] Transport of industrial chlorine gas has resulted in fatal accidents, and chorine gas has been used as a chemical weapon.[14]

Producing new MEA is associated with significant greenhouse gas emissions involving a similar supply chain to natural gas-based fertilizer production.[15] When used to capture CO_2 emissions, MEA degrades, releasing chemical carcinogens such as nitrosamines that, according to one study, "are toxic and carcinogenic to humans even at extremely low levels."[16] At power plants, carbon capture operations using MEA can have air emissions of MEA up to 0.8 kilogram per metric ton of CO_2 captured. These emissions rates can exceed toxicity limits for drinking water and aquatic ecosystems.[17]

In addition to air emissions, MEA CO_2 capture systems generate large quantities of MEA-contaminated liquid waste.[18] Historically, this waste was incinerated or landfilled, but neither of these disposal strategies are economically or environmentally sustainable, especially at much larger scales.[19]

Long-term Storage of CO_2 Is a Scam

Right now, around 95 percent of all captured carbon in the United States is used for enhanced oil recovery, a process of producing oil by injecting CO_2 mixed with other chemicals in existing wells to flush out additional oil.[20] This is far from a climate solution; EOR results in more carbon emissions than it stores. A ton of CO_2 produces two to three barrels of oil when injected; when burned, that oil emits around 1.2 tons of CO_2.[21]

The other option with captured carbon is to store it underground. But CO_2 sequestration also carries significant risks. CO_2 must be injected under sufficient pressure to displace existing fluids. In small spaces, this can create rapid pressure increases that fracture containment layers.[22] Earthquakes from injection can also rupture storage seals, allowing CO_2 to leak.[23] Since many storage locations are in and around fossil fuel reservoirs, abandoned oil and gas wellbores provide a pathway for CO_2 leaking to the surface.[24] CO_2 can also slowly escape along well linings and has been shown to corrode materials used in well casings and seals.[25]

Not only does CO_2 injection carry similar risks to wastewater injection (associated with technologies such as fracking), but reducing pressure to inject CO_2 may require extracting wastewater from the reservoir and reinjecting it elsewhere.[26] The precise constituents of the wastewater vary depending on the geology of the extraction site,[27] but it can contain salts (chlorides, bromides, and sulfides of calcium, magnesium, and sodium), metals (barium, manganese, iron, and strontium), oil, grease, dissolved organics (benzene and toluene), and radioactive material (radium-226).[28] These chemicals can cause cancer, disrupt the endocrine system, affect the nervous, immune, and cardiovascular systems, and affect sensory organs and the respiratory system.[29] Underground injection of wastewater can put aquifers and drinking water at risk,[30] and extensive research links fluid injection and disposal to earthquakes.[31]

Conclusion

Instead of betting on speculative, dangerous, and ultimately climate-destroying carbon capture technologies, the United States must embrace real climate solutions that already work. Off-the-shelf technologies such as wind, solar, and batteries that generate and store carbon-free electricity are more than capable of addressing the climate crisis, at costs far lower than carbon capture.

Methodology

Food & Water Watch created an average emissions intensity for electricity generation in the United States using data from various sources. This includes 2019 electricity use and fossil fuel consumption data from the U.S. Energy Information Administration, CO_2 emissions data from the U.S. Environmental Protection Agency's Inventory of U.S. Greenhouse Gas Emissions and Sinks, and methane emissions data from peer-reviewed academic sources.[32] Electricity requirements for DAC are from a plausible estimate presented in a peer-reviewed academic review.[33] Cost comparisons are based on levelized costs from Lazard.[34] Full calculations and treatment of small electricity sources (biomass, waste to energy, etc.) are on file with FWW.

Endnotes

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