Explainer Series: What is Carbon Capture?

Carbon dioxide (CO_2) is a potent greenhouse gas that occurs naturally and is a byproduct of human activity. It and other gases contribute to atmospheric warming [1,2]. The Intergovernmental Panel on Climate Change has noted the importance of preventing global temperature increases by limiting carbon dioxide released into the atmosphere [1, 2, 3].

Man-made CO_2 emissions result from industrial processes, power generation, and transportation [1,2]. There is biological carbon sequestration, where trees, plants, soil, and oceans can capture and store some carbon dioxide as part of natural processes [4]. Scientists have developed a concept of capturing produced carbon and storing or using it to keep it out of the atmosphere. This is called carbon capture, also known as carbon capture and storage (CCS) or carbon capture, utilization, and storage (CCUS).

What It Means To "Capture" Carbon

The carbon capture process involves trapping carbon created by any number of processes before it is released into the atmosphere. Carbon capture can also involve pulling carbon dioxide out of the air after it has been released. Trapping carbon at its source before it is released into the atmosphere is called point-source carbon capture. Removing carbon dioxide directly from the atmosphere is known as direct air capture.

What is Carbon Sequestration and Storage?

After capturing carbon as a gas, it is condensed into a liquid-like substance at high pressure. It can then be transferred by pipelines, trucks, and ships, eventually permanently stored underground [1,2,4]. CO2 can be pumped into old oil/gas wells, saline deposits, coal deposits that are not financially viable to harvest, and areas of water that are unsafe for drinking [1, 2, 4, 5]. This is the storage part of carbon capture and storage, called sequestration [4].

In certain areas of the U.S., CO2 is injected into low-producing oil wells to force out more oil, referred to as enhanced oil recovery [1, 2]. Captured CO_2 has also been reused as an ingredient in manufacturing certain materials or to grow algae or bacteria for animal feed or agricultural fertilizer [1].

Development of CCS technology

Carbon capture projects have operated for around 52 years in the United States, having existed since 1972 [6]. As of 2022, over 150 carbon capture and storage projects exist globally, with around 60 of these projects appearing between 2019 and 2022 [6].

Safety Considerations for Carbon Capture:

Carbon must be injected into wells at high pressure to be sequestered underground. There are concerns that sequestration processes may risk clean water aquifers and/or induce seismic activity [2].

Carbon sequestration projects are subject to Environmental Protection Agency (EPA) regulations, including the 1974 Safe Drinking Water Act, which protects underground clean water aquifers from possible impacts [2]. The EPA's Underground Injection Control Program requires each carbon capture project to know the area's seismic activity before a permit can be issued [2]. Next, the Clean Air Act and the Greenhouse Gas Emissions Program require long-term monitoring, reporting, and verifying (or MRV) to record the plan for safe CO_2 injections [2].

Why Explore CCS?

Carbon capture is crucial for alternative fuels like hydrogen because it addresses the environmental impact of fuel production and use.

Hydrogen energy can be produced from methane using a process known as steam methane reformation, which generates CO_2. Carbon capture technologies mitigate this by capturing the emissions before they are released into the atmosphere, reducing the carbon footprint associated with hydrogen production. By integrating carbon capture into hydrogen production processes, industries can significantly enhance the environmental credentials of hydrogen as a viable alternative fuel [7,8].

Regulatory Considerations:

The ownership of the underground pore space for carbon and the rights of owners hosting storage need to be determined by regulation or legislation [9]. Some states have determined that the surface property owner also owns the "pore space" beneath it where carbon could be stored and may be sold or leased to others [9]. In a North Dakota court, it was ruled that those who own the land above the surface must be compensated when mineral resource companies use open pore space for storage or disposal [9]. A consistent rule or law regarding this aspect of CO_2 injection and storage is needed across the U.S. to scale the technology [9].

Legislation is also needed to guarantee ongoing monitoring of injected CO_2 to mitigate leaks and determine the legacy financial responsibility for this obligation [5]. Transport of CO2 by pipeline is another emerging regulatory issue [10], as the current governmental and legal environment makes the permitting process difficult.

What about in Pennsylvania?

Pennsylvania is a major emitter because of its natural gas and coal production [10,11,12]. Carbon capture and storage projects in Pennsylvania are estimated to be able to store "2.4 billion metric tons of CO_2 underground," which can be imagined as the amount of "CO_2 emitted a year by 500 million gas vehicles" [11]. These projects could also allow coal and natural gas-fired power plants to mitigate the CO_2 produced while remaining in operation [10, 12]. However, there are risks regarding pipelines with eminent domain considerations, such as the cost of projects, impact on stakeholders, regulation, and whether CCS projects encourage support for fossil fuels [10, 11]. Pennsylvania's Department of Conservation of Natural Resources has been working to understand the possible reservoirs that store CO_2, what happens in oil fields filled with CO_2, and how to work with other states on storing CO_2 [13]. Furthermore, legislation was recently approved by the state Senate to establish a framework for regulating CCS. If this continues through the legislative process and becomes law, it will be an important step in bringing at-scale CCS projects to the state.

References & Resources

[1] Herzog, H. (2023, January). *Carbon Capture*. MIT Climate Portal. climate.mit.edu/explainers/carbon-capture

[2] *Carbon capture*. Center for Climate and Energy Solutions. (2023, August 30). www.c2es.org/content/carbon-capture/

[3] *How does carbon dioxide increase Earth's temperature?* Natural History Museum. (n.d.). https://www.nhm.ac.uk/discover/quick-questions/how-does-carbon-dioxide-increase-global-temperature.html

[4] *What is carbon sequestration and how does it work?*. CLEAR Center. (2022, July 28). clear.ucdavis.edu/explainers/what-carbon-sequestration

[5] *Understanding carbon capture and storage*. British Geological Survey. (2022, November 16). www.bgs.ac.uk/discovering-geology/climate-change/carbon-capture-and-storage/

[6] *What is carbon capture and storage? CCS explained*. National Grid Group. (n.d.). https://www.nationalgrid.com/stories/energy-explained/what-is-ccs-how-does-it-work

[7] *Hydrogen production: Natural gas reforming*. Energy.gov. (n.d.). www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

[8] *Methane steam reforming*. Methane Steam Reforming - an overview. (n.d.). https://www.sciencedirect.com/topics/engineering/methane-steam-reforming

[9] Oyewunmi, T. (2023, June 7). *Underground property rights for Carbon Capture*. Kleinman Center for Energy Policy. https://kleinmanenergy.upenn.edu/news-insights/underground-property-rights-for-carbon-capture/

[10] Clinton Climate Initiative. (2009, November 1). Viability of a Large-Scale Carbon Capture & Sequestration Network in Pennsylvania.https://elibrary.dcnr.pa.gov/GetDocument?docId=1743513&DocName=Viability-of-a-Large-Scale-CCS-Network-in-PA-2009.pdf

[11] Levy, M. (2024, April 9). *Pennsylvania makes a push to attract and approve carbon capture Wells*. AP News.

https://apnews.com/article/pennsylvania-epa-biden-carbon-capture-hydrogen-33d86e1322590d491c0e542b36478fca

[12] Great Plains Institute. (2024, March 8). *Pennsylvania Carbon Capture Opportunities*. Carbon Capture Ready. https://carboncaptureready.betterenergy.org/pennsylvania/

[13] *Carbon capture utilization and storage*. Pennsylvania Department of Conservation & Natural Resources. (n.d.). https://www.dcnr.pa.gov/Conservation/ClimateChange/CarbonCaptureStorage/Pages/default.aspx