LRO SNAPSHOT

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Achieving Net-Zero Emissions: The Role of Carbon Capture and Sequestration

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As global endeavors to achieve net-zero emissions by 2050 intensify, investments and research projects are focusing on carbon dioxide removal (CDR) technologies. Carbon capture or carbon sequestration plays a pivotal role in this process by minimizing the volume of carbon dioxide (CO_2) emissions released into the earth's atmosphere.

CO_2 emissions, both natural and man-made, are widely recognized as a primary contributor to climate change. Natural emissions originate from animals, plants, and wildfires, whereas energy production and fossil fuel combustion are key sources of anthropogenic emissions.

In 2022, the International Energy Agency (IEA) reported a 321-megatonne (Mt) increase in global energy-related CO_2 emissions, totaling nearly 37 gigatonnes (Gt). In the United States alone, CO_2 emissions in 2022 rose by 36 Mt from the previous year, reaching almost 5 Gt.

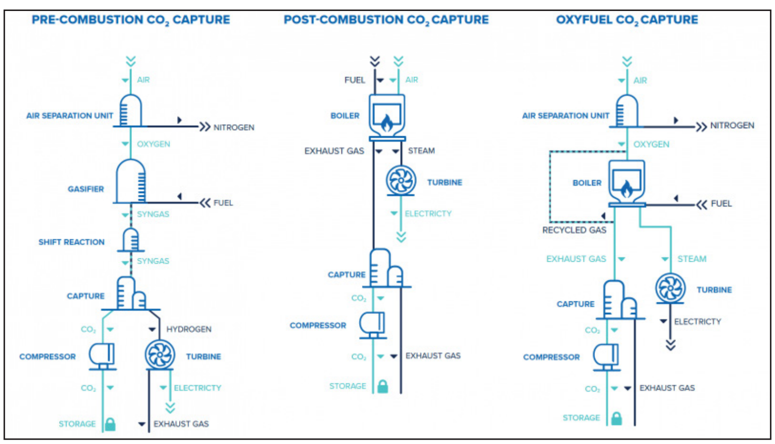

Image Credit: Global CCS Institute

Understanding Carbon Capture

Carbon Capture and Sequestration (CCS) involves capturing CO_2 directly from power plants and other industrial facilities, then transporting and storing it in underground geological formations to prevent its release into the atmosphere. Though not a new concept, advancements in technology and methods continue to improve the efficiency and affordability of carbon capture, fueling its recent momentum.

Even as these high-tech strategies are being pursued, agriculture could make another significant contribution by adopting management practices like reduced tillage and cover cropping which support natural carbon sequestration in the form of soil organic matter as encouraged by the Resilient Soils and Water Quality Act (2022 - LB925).

The Impact of CO_2 Emissions

The CO_2 concentration in the earth's atmosphere is measured in parts per million (ppm). In 2022, the National Oceanic and Atmospheric Administration recorded an average ppm of 421 at Hawaii's Mauna Loa Atmospheric Observatory. In contrast, pre-industrial levels were around 280 ppm. It is estimated that human activity has produced 1.5 trillion tons of CO_2 pollution since then.

Purpose and Methods of Carbon Capture

The central aim of CO_2 capture is to reduce greenhouse gas emissions, a significant factor in climate change. CO_2 is naturally secured and stored by the earth's oceans, plants, and trees. However, with escalating emissions and the need to lower atmospheric CO_2 at a larger scale to achieve net-zero emissions, innovative methods of CO_2 capture are necessary.

Approaches to Carbon Capture

Direct Air Capture (DAC) involves extracting CO_2 emissions directly from the atmosphere, analogous to how an air purifier functions in a home. Large, high-powered fans draw in air and remove CO_2 through a series of chemical reactions. Once separated, purified, and compressed, the CO_2 is stored in underground geological formations. The IEA reports that there are 18 DAC plants operating globally, capable of capturing nearly 0.01 Mt of CO_2 annually.

Several strategies are used around the world to capture CO_2 emissions, including pre-combustion, post-combustion, and oxyfuel capture.

Pre-combustion involves capturing CO_2 before combustion occurs. Fossil fuels are gasified to create a mixture of hydrogen and CO_2, enabling the hydrogen to be separated and burnt without generating CO_2. The CO_2 can then be compressed, transported, and stored.

Post-combustion capture, commonly used at power plants and other industrial facilities, involves capturing CO_2 from the gases these facilities generate. CO_2 is typically extracted using a liquid solvent or other separation techniques. The CO_2 captured by this method is often repurposed for the food and beverage industry.

Climeworks DAC collector technology used at their Orca plant in Iceland. Image Credit: Climeworks

Oxy-fuel combustion entails burning fuel with oxygen and recycled flue gas. The use of oxygen instead of air results in exhaust gas primarily consisting of water vapor. This makes it easier to separate out a high purity CO_2 stream.

Direct Air Capture in Action

In late 2021, Swiss company Climeworks AG launched Orca, the world's first and largest DAC plant. Located in southwest Iceland, the Orca facility captures and stores 4,000 metric tons of CO_2 annually, powered by a nearby geothermal power plant. Climeworks is expanding their presence in Iceland with the ground breaking of an additional DAC plant, Mammoth. Planned to become operational in 2024, Mammoth is estimated to have the capacity to capture 36,000 tons of CO_2 annually.

The Climeworks DAC technology operates in three steps. A fan draws air into a filter that traps CO_2 particles until full. Once the filter is saturated, it closes, and its temperature is raised to about 212 degrees Fahrenheit (100 degrees Celsius). This causes the filter to release the trapped CO_2, which is then collected and injected underground.

The Transportation of CO_2

Once the CO_2 emissions are captured, they are typically transported to a designated storage site. The most common method of transport is through underground pipelines, joining the extensive pipeline network in the United States that already carries liquid and natural gas across the nation.

Transporting CO_2 through pipelines is a long-established method in the United States, and globally. For over five decades, CO_2 has been transported via pipelines across the U.S.

As per the Global CCS Institute, nearly 5,000 miles of pipeline in the U.S. transport around 70 million tonnes of CO_2 annually. During the capture process, CO_2 is compressed into a fluid-like state, facilitating its movement through pipelines. Moreover, CO_2 is relatively safe to transport as it is non-flammable and non-explosive.

The National Energy Technology Laboratory (NETL) projects significant growth in U.S. transportation capabilities, aiming to transport 65 million metric tons of CO_2 annually by 2030 and one gigatonne of CO_2 by 2050.

U.S. CO_2 Storage Capabilities

The U.S. has the capacity to store its captured CO_2 within its geological formations. With the potential to store 2.6 trillion tons of CO_2, the U.S. has enough capacity to store historical and future emissions for centuries.

Studies conducted by the Energy and Environmental Research Center (EERC) and the Department of Energy (DOE) suggest that North Dakota alone, with a geological storage capacity of 250 billion tons, could store all the CO_2 emissions from the U.S. for the next 50 years.

Summit Carbon Solutions has invested $4.5 billion in the Midwest Carbon Express, which will include 317 miles of pipelines running through 14 Nebraska counties from six capture facilities.

This project, spanning five states, will be able to store 12 million metric tons of CO_2 annually, equivalent to the CO_2 emissions from 2.6 million vehicles each year.

CO_2 is stored at least one kilometer underground, where the pressure and temperature turn it into a supercritical fluid. As explained by the NETL, CO_2 must reach a critical temperature above 88 degrees Fahrenheit and a pressure above 72.9 atm to become a supercritical fluid, a state it will likely maintain due to the depth of sequestration.

Various types of geological formations serve as potential CO_2 storage sites. These include sedimentary basins, oil & natural gas reservoirs, unmineable coal, saline formations, basalt formations, shale basins, and offshore CO_2 storage.

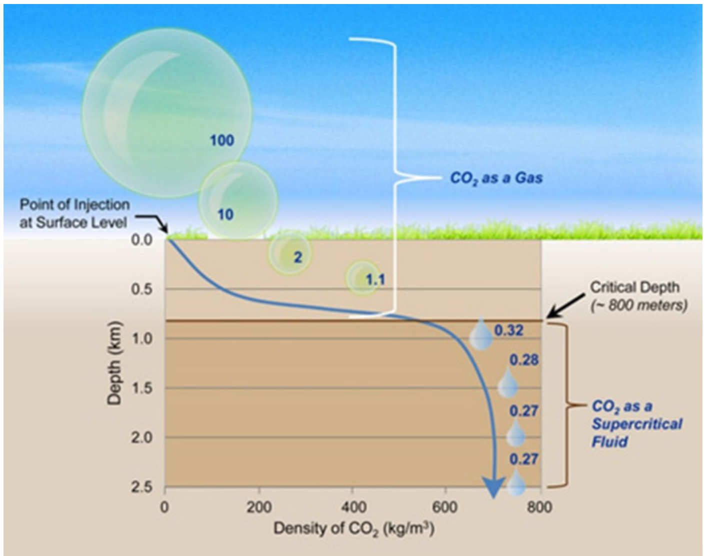

Image Credit: National Energy Technology Laboratory

Methods to Trap CO_2 Underground

To prevent the sequestered CO_2 from returning to the atmosphere or migrating from injection sites, it must be effectively trapped underground. The DOE identifies four primary mechanisms for trapping injected CO_2: structural, residual, solubility, and mineral trapping.

Structural trapping prevents vertical migration of CO_2, with rock layers and faults acting as seals. Residual trapping occurs when migrating CO_2 is trapped in the pore spaces between rock grains. Solubility trapping involves the dissolution of CO_2 into brine water in rock pore spaces, with some dissolved CO_2 forming bicarbonate (HCO_3). Mineral trapping occurs when dissolved CO_2 reacts with minerals in the rock, leading to permanent trapping.

Enhanced Oil Recovery (EOR) and CCS Projects

EOR uses a pipeline to deliver and inject CO_2 into oil fields, storing CO_2 permanently and aiding in the extraction of remaining oil. Over 100 commercial CO_2 injection projects have seen success in this area, with over 2 billion cubic feet of CO_2 injected and over 280,000 barrels of oil produced daily in the U.S.

The Quest Carbon Capture and Storage facility, operated by Shell Canada, illustrates the potential of these technologies. With ambitions to become net-zero by 2050, Shell has invested heavily in CCS programs. The Quest CCS facilities will soon capture and store over one million tons of CO_2 annually. Shell operates three CCS facilities globally, with eleven projects in development, including two sites in the U.S.

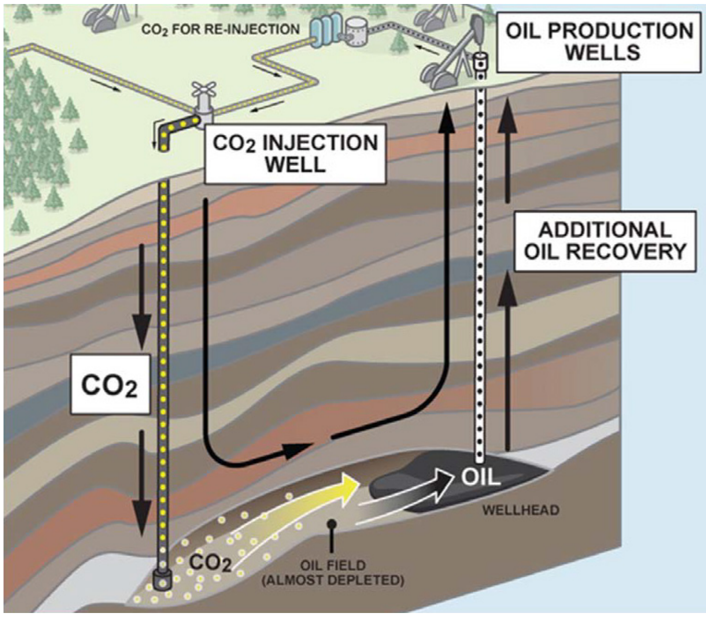

Image Credit: U.S. Department of Energy

Nebraska's Storage Capabilities

According to the NETL, Nebraska's most significant CO_2 storage potential lies in its underground saline formations. The state could store up to 112 billion metric tons of CO_2 within these formations. Nebraska has immense CO_2 storage potential, and several projects are already in development.

Nebraska's Approach to CCS Legislation and Policy

In 2021, the Nebraska Legislature enacted the Nebraska Geological Storage of Carbon Dioxide Act (2021 – LB650), thereby establishing a legal and regulatory framework to facilitate potential CCS projects in Nebraska. Recently, states in which pipeline projects are progressing have introduced measures to protect property owners and create utilities board oversight. In 2023, Nebraska enacted LB562 which will increase availability of E15 motor vehicle fuels and, it is hoped, overall sales of corn-based ethanol. Projects being pursued in the corn-belt will reduce ethanol's CO_2 footprint and help maintain its role as a substitute for non-renewable petroleum fuels in the transportation sector.

Summit Carbon Solutions has partnered with 30 ethanol plants to construct a project that runs across a five-state region

Image Credit: Summit Carbon Solutions

Nebraska Carbon Capture Sequestration Projects

Several significant projects are already underway in Nebraska.

Carbon America and Bridgeport Ethanol, LLC are collaborating on a project slated to commence CO_2 injections in 2024. The project aims to capture and store 175,000 tons of CO_2 annually, accounting for 95 percent of the Bridgeport facility's total emissions.

Omaha-based company Navigator CO_2 Ventures, LLC has proposed the Heartland Greenway project, which involves constructing approximately 1,300 miles of new pipelines and capture facilities. Upon completion, the project expects to store around 15 million metric tons of CO_2 annually at an underground storage site in south-central Illinois.

Summit Carbon Solutions is spearheading a $4.5 billion investment in the Midwest Carbon Express project, which spans five states, including Nebraska. Upon completion, it is expected to be the world's largest CCS project, capturing and storing up to 12 million tons of CO_2 annually.

Conclusion

While still in development, carbon capture and sequestration technologies are among the strategies being explored to achieve the goal of net-zero by 2050.

In order for the world to reach the stated net-zero emission goals by 2050, further advancements and developments in carbon capture technology are vitally important.