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Balancing Cost vs. Reward in Carbon Capture Streams

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Global interest in decarbonization is rising across industries, corporations and countries, driven in part by the Paris Climate Agreement, which aims to limit global warming below 2 degrees Celsius compared to pre-industrial levels and reduce global greenhouse gas emissions. As an increasing number believe carbon capture and storage programs should be part of the solution, new government incentives may give them the chance to find out.

A total of 21 carbon capture, utilization and storage (CCUS) facilities were operating globally in 2020, capturing 41 million tons of carbon dioxide (CO_2) annually, according to an International Energy Agency special report. Of these facilities, 10 are located in the U.S., and half of these plants capture CO_2 from natural gas processing plants. The CO_2 for the remaining five facilities comes from a coal fired power plant and industrial facilities producing synthetic natural gas (syngas), hydrogen, fertilizer and ethanol.

The number of carbon capture and storage (CCS) projects continues to grow worldwide, with 135 facilities now in the pipeline — over 70 of which were added in 2021 alone, according to a report from the Global CCS Institute.

The CO_2 captured from these facilities is primarily used for enhanced oil recovery (EOR), a process that uses the gas to recover additional oil out of a well that could not otherwise be retrieved. Traditionally, most CO_2 used in EOR came from naturally occurring reservoirs. In places where CO_2 is not readily available from a natural source, industrial sources of captured CO_2 may be considered.

Interest in CCUS is driven by a global focus on reducing carbon emissions and government incentives or penalties that fuel it.

On the incentive side, Section 45Q of the U.S. tax code offers tax credits for projects that capture CO_2 from industrial sources and either store it permanently and securely in a geologic formation, or sell it for use in EOR or other industrial processes such as methanol or fertilizer production or food and beverage applications.

When enacted a decade ago, 45Q primarily targeted coal-fired and combined-cycle gas turbine power plants, and it capped the amount of CO_2 that would qualify for the credits, valued at $10 per metric ton for EOR and $20 per metric ton for geologic storage. As of late 2021, a CCUS facility is installed at only one U.S. power plant, and it is currently not in operation.

To attract additional investment, Congress lowered the threshold for 45Q eligibility in 2018 while also increasing the credit's value. Today, at the end of 2021, chemicals, oil and gas companies are among those eligible for escalating tax credits that in 2026 will reach $35 per metric ton for EOR and $50 per metric ton for geologic storage, with no cap on volume. The credits are currently available on CO_2 captured and stored for 12 years after the project is placed in service. In addition, the U.S. Energy Act of 2020 authorized more than $6 billion for CCUS research, development and demonstration projects.

To meet emission reduction targets in the Paris Climate Agreement, Canada is taking a different approach. The government enacted the Greenhouse Gas Pollution Pricing Act in 2018, which establishes minimum national standards for carbon pricing. All companies that have significant point sources of CO_2 are required to pay or submit offset credits based on the portion of their CO_2 emissions that exceed an annual output-based limit. The escalating price of carbon will reach 50 Canadian dollars per metric ton in 2022 and will escalate to 170 Canadian dollars by 2030. Proceeds are returned to the jurisdiction where they are collected and can be used to support industrial projects, as well as offset costs to individuals and businesses impacted by the resulting higher energy prices.

In addition to these incentives and penalties, some corporations have set internal targets for decarbonization and will be measuring corporate performance against these goals. The capital and operating costs of adding CCUS is high, and the payout on the CO_2 product usually does not provide a high return on investment. Incentives and other Environmental and Social Governance (ESG) benefits may drive these projects forward. Some facilities such as refineries may contain multiple CO_2 streams each with unique characteristics. Selecting which streams to target for carbon capture depends on a variety of factors, from the volume and concentration of the CO_2 in the stream to the potential contaminants that must be removed while balancing the capital cost of the retrofits needed to install the technology.

Choosing Among CO_2 Streams

When considering decarbonization options in refineries and other industrial facilities, there are two categories of CO_2 sources that can be captured: the low-concentration CO_2 streams generated by combustion of fuel, and the high-concentration CO_2 streams produced as part of a chemical reaction or treatment process.

Dilute low-pressure CO_2 streams: Commonly referred to as post-combustion sources, dilute CO_2 streams are a product of fuel combustion. These normally high-volume streams have low concentration of CO_2, typically 15% to 22% by volume. Depending on the fuel used, these streams may also contain nitrogen, oxygen, sulfur dioxide, nitrogen oxides or other components. Typical sources of dilute low-pressure CO_2 within a refinery or industrial facility include fired heaters that generate heat for a process unit, utility boilers that provide steam for use throughout a facility, or combustion turbines used for either power generation or rotating equipment drivers.

High-pressure CO_2 streams: Pressurized CO_2 streams also exist in refineries and industrial facilities. These streams may be a byproduct of a chemical reaction, or they may be a waste stream generated when CO_2 is removed from a process stream. Concentrations of CO_2 in these streams have a much wider range of CO_2 percentage by volume. Typical examples of high-pressure process streams are those generated in the steam methane reforming (SMR) process used in hydrogen and ammonia production, or generated in the CO_2 stream resulting from syngas cleanup.

Concentrated CO_2 streams: These streams are the most accessible, as they typically contain CO_2 and water and require very little cleanup. The classic example is a concentrated stream of CO_2 produced at an ethanol plant as a byproduct of the fermentation process. Other concentrated streams are those that result from the purification of natural gas in a gas processing or liquefied natural gas (LNG) facility.

Treatment Requirements

The treatment required for CO_2 streams varies according to the stream's composition and the product specifications for the intended end use or disposal location of the CO_2.

For post-combustion dilute CO_2 streams, treatment typically consists of a multistep process that begins with gas cooling, followed by absorption with an amine-based or physical solvent that selectively absorbs the CO_2 in a liquid phase. The rich solvent containing the CO_2 is then regenerated using heat to drive off the CO_2 as a gas stream. Next, the CO_2 stream goes through a dehydration process to remove any water, and then it is compressed to the required pipeline disposal pressure. Given the lower concentration of CO_2 in these high-volume flue gas streams, as well as the low pressure of the post-combustion streams, treatment equipment is large and compression costs can be significant.

By comparison, concentrated CO_2 streams typically only require dehydration and compression prior to disposal or use. These streams tend to have much smaller flow rates than post-combustion streams.

Considering Finances

Decisions about whether or how to take advantage of carbon capture opportunities depend on a variety of factors, beginning with an evaluation of financial feasibility. The levelized cost of CO_2 capture is a common way to evaluate carbon capture alternatives. This method includes an evaluation of both the capital cost of the treatment process and the operating cost of treating and handling the CO_2 product, levelized over a 20-year period. To determine if the installation cost is justified, the cost of CO_2 capture on a cost-per-ton basis can then be compared to any financial incentives or penalties.

To take advantage of economies of scale, it may make economic sense for the flue gas from two, three or more process heaters to be captured, combined and treated together in a single unit. This combined approach must be balanced with the cost to combine the streams that may not be adjacent as well as the steam demand for larger units, as a refinery may need to add boilers to generate the required amount. New boilers compound the CO_2 emissions with additional flue gas.

In addition to financial incentives, an increasing number of eyes are focused on reducing carbon emissions across the globe. The goals set by the Paris Climate Agreement, as well as national, state and local emission regulations, all point to the adoption of CCUS solutions. Investors who evaluate public companies using ESG criteria will increasingly screen for corporate participation in carbon capture projects.

Next Steps

Carbon capture technologies and utilization and storage solutions will continue to evolve as more innovation occurs and more projects take shape.

For those interested in participating, it is time to start planning and utilizing available funding for CCUS projects. As our industry learned when implementing selective catalytic reduction technologies and reducing sulfur dioxide emissions, the process before us will not be easy. But the benefits to the energy sector, the environment and the future of our planet make it worth the effort.

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