WHITE PAPER

Carbon Capture Market is Marching Forward

By Nicholas Klein and Tisha Scroggin-Wicker, PE

Carbon capture, utilization and storage (CCUS) technologies make it possible to prevent up to 95% or more of a power plant's carbon dioxide emissions from entering the atmosphere. The Inflation Reduction Act (IRA) of 2022 established a significant revenue stream that carbon capture facilities can leverage, leading to a successful project economic pro forma.

Faced with renewable energy requirements and carbon dioxide (CO_2) reduction goals and mandates, utilities with aging coal-fired power plants or industrial hydrogen producers have had few choices other than to plan their plants' retirements. Carbon capture provides an opportunity for these facilities to support decarbonization goals, generate lower carbon intensity power and reinvent their purpose by generating revenue through the capture of carbon.

Carbon capture technologies make it possible to remove CO_2 from plant emissions. Existing power plants retrofitted, and new plants outfitted with carbon capture systems have the potential to continue supporting jobs in their communities and extending their operating lives by a decade or more.

When installing carbon capture systems, utilities must consider how they will dispose of and benefit from the large amounts of captured CO_2. Currently, there are two predominant options. One is geological sequestration, which involves injecting the CO_2 into very large underground geological formations for permanent storage and sequestration. That means disposing of CO_2 as a waste product, which requires costly infrastructure and permitting, along with overcoming potential public opposition. This option is highly location-dependent, likely requiring a facility to be near the required geologic formation or a CO_2 transport pipeline to remain economically feasible. Leveraging existing or new pipeline networks for the transport of CO_2 is a potential transportation avenue. Securing permits for new CO_2 pipelines, especially interstate pipelines, has thus far been challenging but pipeline development continues to progress and advance.

Another option is to sell the CO_2 to the oil industry for enhanced oil recovery (EOR). Oil companies utilizing CO_2 for EOR are typically willing to pay for the CO_2, since they currently rely on natural CO_2 sources found underground. Captured CO_2 can be used to replace and supplement these resources. The potential supply of CO_2, however, greatly exceeds likely demand from EOR utilization. This option is also highly dependent on the proximity of the plant to CO_2 pipelines or oil fields with sufficient capacity to transport the captured gas.

Does the installation of a carbon capture system make economic sense? This is the question a growing number of utility and power producers are asking, and projects in development are expected to provide the answer.

DOE Funding Initiative

As a result of recent legislation, the U.S. Department of Energy (DOE) has been able to offer unprecedented levels of funding for carbon capture projects. Within the Infrastructure Investment and Jobs Act (IIJA) passed in 2021, the DOE allocated $3.5 billion combined for demonstrations and pilots along with $2.5 billion for the development of large-scale carbon storage commercial projects. Additionally, $310 million for carbon utilization applications and $100 million for technology and front-end engineering and design (FEED) projects were allotted.

Additional funding was made available through IIJA for direct air capture (DAC), involving $3.5 billion for multiple hubs across the country to capture and either store or make use of CO_2. Prizes worth $115 million are also obtainable in technology competitions for creative processes seeking to develop DAC as a viable approach for carbon removal.

To jump-start the commercialization of carbon capture technologies, the DOE recently announced $189 million in available awards for nine FEED studies associated with carbon capture demonstration projects. These studies involve an assortment of carbon capture technologies and sites, including coal, integrated gasification combined-cycle, natural gas combined-cycle, cement and cogeneration facilities. DOE funding has been earmarked for projects designed to accelerate the deployment of existing carbon capture technologies and the development and refinement of new ones, as well as the assessment and verification of commercial-scale CO_2 storage. By deploying a variety of large-scale CCUS pilot and demonstration projects, the DOE expects to build the knowledge base needed to test and further prove the viability of carbon capture technologies on a commercial scale.

45Q Tax Credits

The new 45Q tax credits set forth in the IRA of 2022 form the economic engine propelling this market forward. Section 45Q of the Internal Revenue Service tax code has been substantially updated to increase incentives per metric ton of CO_2 to $60 for utilization or EOR, and $85 for sequestration, if apprenticeship and prevailing wage requirements are met. The minimum carbon capture requirements that power plants need to meet to be eligible for these tax credits include capturing at least 75% of CO_2 emissions and 18,750 metric tons of CO_2 annually. Similar to the 2018 update, these credits would be accessible for 12 years after a project begins operation. DAC sites must capture at least 1,000 metric tons of CO_2 annually in order to qualify for tax credits assessed per metric ton of CO_2 that are $130 for utilization or EOR and $180 for sequestration if applicable conditions for apprenticeship and prevailing wages are reached.

The IRA also provides the option for these tax credits to be issued through direct payments to for-profit entities (for up to five years after the initial operation date) and tax-exempt organizations (for up to the full 12 years after the initial operation date). Additionally, there is potential for transfer or sale of part or all of these tax credits.

The 45Q rule lays out the relevant qualification requirements. To receive the tax credit for geologic storage, a utility must meet the U.S. Environmental Protection Agency's (EPA) sequestration reporting rules (40 CFR Part 98, Subpart RR), which include a monitoring, reporting and verification plan that documents the amount of carbon injected and stored. Entities seeking credits for EOR have the choice of satisfying either EPA regulations governing geological CO_2 sequestration or the CO_2 storage guidelines developed by the International Organization for Standardization (ISO) and the American National Standards Institute (ANSI) (CSA/ANSI ISO 27916:19).

The rules also outline that the IRS can recapture the credit if the carbon is intentionally leaked or withdrawn from storage. Once the carbon capture system begins commercial operation, the IRS can reclaim the credit up to the earlier date of three years after the date the tax credit is last claimed or the date when monitoring ends.

Together, these 45Q changes make implementation of carbon capture technology a more economically attractive proposition for utilities while not limiting the industry with a tax credit cap. There is, however, a catch: To be eligible, construction of these projects must commence by Jan.1, 2033.

Carbon Capture and Storage Technologies

Utilities and others contemplating post-combustion carbon capture projects have several options to choose from that are in varying stages of development. Processes in this space include membranes, adsorption with solid state sorbents, cryogenics, enzymes and chilled ammonia. Absorption through liquid solvents, primarily amines, is the most common carbon capture method currently being assessed and deployed.

Originally developed in the 1930s, amine technology has been used for decades in a variety of applications, including post-combustion carbon capture. Amine processes have become the primary method used by power plants, with proven capabilities of removing 95% or more of CO_2 from emissions. Amines are chemical solvents that undergo a reversible reaction with CO_2 and other acidic gases. During the amine-based process, when exhaust gas containing CO_2 comes in contact with a liquid amine solution, the CO_2 chemically binds to the amine molecules and is removed from the gas stream. This amine solution can be pumped into a separate column where heat is used to reverse the process, stripping the high-quality CO_2 from the amine. The CO_2 can then be compressed for EOR use or injected into a suitable geological formation for storage.

Many DOE-funded carbon capture projects to date employ amine-based processes. The differences between individual processes are primarily in their “secret sauce” — the proprietary chemicals used to increase the efficiency of the amine solution. Researchers continue to seek solutions that reduce the amount of auxiliary power and water amine-based systems need to capture and recover carbon, as well as the volume of steam and heat these processes consume during regeneration.

Efforts are also underway to minimize their relatively high capital, operating and installation costs. Non-aqueous solvents (NAS) are emerging as potential avenues to lower steam and auxiliary load demands of these facilities by utilizing less water in the capture process. Applying lessons learned in research and operational settings will support future advancements with these and other carbon capture technologies.

Opportunities and Challenges Ahead

Operators of power plants will need to determine not only the right carbon capture solutions for their operation, but also how to efficiently integrate them into their existing systems. Current carbon capture technologies can potentially impact power generation operations and efficiency. An experienced integrator that understands power plant operations and can model carbon capture processes is essential to minimizing potential power production losses and identifying opportunities for process optimization.

Before CCUS systems can be fully commercialized, additional challenges must be addressed:

- **Reduced capacity factors** — The economic feasibility of a carbon capture facility depends on the relative amount of CO_2 captured from the flue gas that can generate an adequate revenue stream. As a result, the carbon intensity of the plant is reduced, which increases the value of the electricity generated at the site for consumers looking to decrease their carbon footprint. This poses special challenges to coal plants facing reduced run times in areas with high renewable energy penetration. Since the early 2000s, the capacity factor of many coal plants has dropped significantly, reducing the economic benefit of the capital investment by over half in many cases. A retrofitted plant may be economical to bid into power markets at similar negative power prices as wind currently enters the market.
- **Sequestration vs. EOR concerns** — Given the increase in 45Q tax credits, power plants appear at first glance to have the most revenue to gain by sequestering recovered CO_2 in geological formations. But that may not be the case, as power plants that can obtain additional incremental revenue selling captured CO_2 to an EOR off-taker have the potential for similar or greater total revenue generation. Plants located near oil fields are likely in a better position to market their captured carbon for EOR use than those that must transport it hundreds of miles or more for sale.
- **Competitive markets** — Independent system operators (ISOs) recognize the potential impact CO_2 reduction strategies can have on the competitive markets the ISOs design and operate. Those markets optimally run with minimal out-of-market influences, such as subsidies or carbon taxes. ISOs, however, must also create markets that properly reflect the economic impact of state and federal regulations, even without the benefit of any oversight of those regulations.
- **Pathway to blue hydrogen** — CCUS provides a pathway to reduced carbon emissions for a variety of industrial processes. In the context of conventional hydrogen production methods, CCUS gives existing hydrogen producers the option to invest in a reduced-carbon future via blue hydrogen. CO_2 from combustion heating processes can be captured using various technologies from these point sources before being utilized for geologic sequestration, EOR, fertilizer synthesis or commercial use. In general, CO_2 is collected, then separated in a cleanup step, transported and delivered to end users.
- **Regulatory support** — Identifying and understanding the requirements of the relevant governing permitting entities is a crucial part of the development process for CCUS projects. The EPA governs CCUS permitting on the federal level, which applies to states without primacy, or the ability to manage their own permitting programs for geological sequestration. North Dakota, Wyoming and Louisiana have received primacy approvals from the EPA, which allows them to administer their own CCUS permitting systems within their respective states. Additional states are involved in various stages of the

EPA's primacy application process. It is also important to note that 45Q requires a monitoring period of geological formations for any leaks that may occur where vested parties could be liable for reimbursement of investment tax credits to the Treasury department. Awareness of the intricacies associated with CCUS permitting and monitoring is key to optimizing value in the set up and operation of CCUS facilities.

Despite its challenges, carbon capture has substantial political, regulatory and academic support that will likely continue to be incentivized through federal legislation, DOE support and state mandates. This provides opportunities for new plants to be designed with carbon capture capabilities in mind and existing sites to have a second life as carbon capture facilities.

About Burns & McDonnell