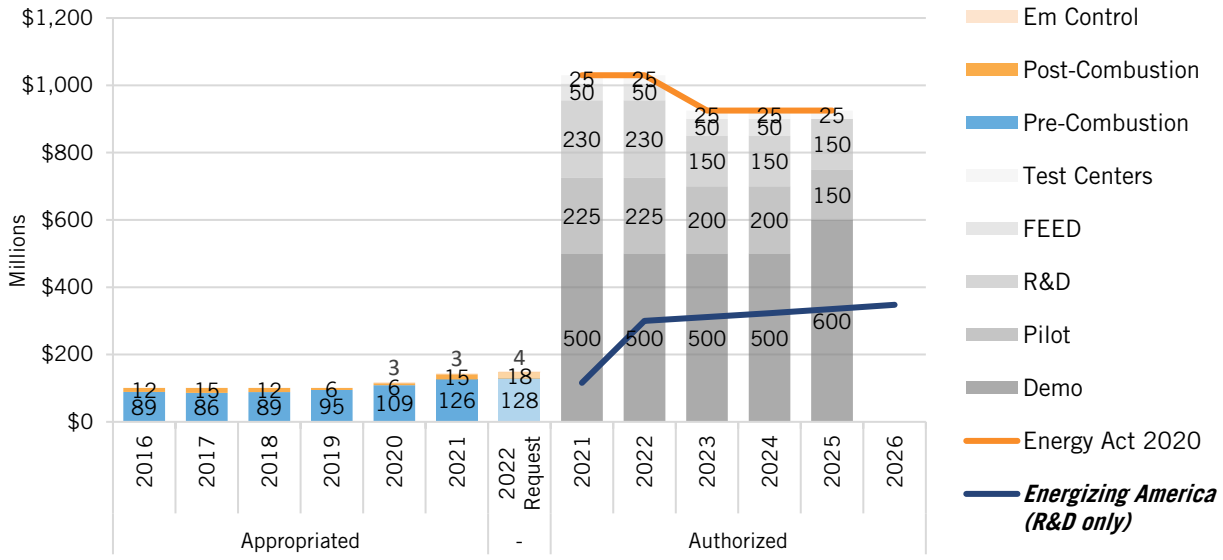
Federal Energy RD&D: Carbon Capture

BY COLIN CUNLIFF AND LINH NGUYEN | JUNE 2021

Carbon capture, utilization, and storage (CCUS) technologies for fossil-fuel power plants have the potential to preserve important options—including coal- and natural-gas-fired electricity generation—in a carbon-constrained future. CCUS will also likely be needed to decarbonize many industrial processes—such as the production of ethanol, fertilizers, plastics, cement, and steel—for which low-carbon alternatives are not currently available.[1] The 2018 Intergovernmental Panel on Climate Change (IPCC) special report on 1.5°C of warming found that CCUS plays an essential role in nearly all deep decarbonization pathways.[2] The Department of Energy's (DOE) carbon capture research, development, and demonstration (RD&D) program was largely limited to coal in the past. The Energy Act of 2020 provides a much-needed expansion of carbon capture RD&D to other sources of emissions and prioritizes demonstration projects in order to address the technical challenges unique to each type of facility.

Figure 1: The Energy Act of 2020 provides a significant reorganization of carbon capture activities at DOE.[3]



What's at Stake

CCUS technologies prevent greenhouse gases from power plants and industrial facilities from reaching the atmosphere. The IPCC has found that CCUS is essential to achieving net-zero emissions: The majority of IPCC pathways consistent with 1.5°C of warming project the use of carbon capture and storage on the order of 350 million–1,200 million metric tons of carbon dioxide (MMt CO_2) over the 21st century.[4] The National Academies of Sciences, Engineering, and Medicine (NASEM) found that carbon capture and storage in the United States should grow to ~50–75 MMt CO_2/yr by 2030 (and as much as 250 MMt CO_2/yr by 2035) in order to be consistent with a net-zero emissions by 2050 pathway.[5]

CCUS may be on the cusp of significant new buildouts and cost reductions. DOE's Industrial Carbon Capture and Storage (ICCS) program successfully launched CCUS demonstration projects at the Port Arthur fertilizer facility in 2013, and the Archer Daniels Midland ethanol plant in

2017.[6] The Petra Nova coal power plant began capturing its carbon emissions in 2017 at a cost of about $60 per ton. (Although the plant recently closed due to declining revenues as a result of the COVID-19 pandemic, it was successful in facilitating learning that is projected to lead to 30 percent cost reduction for similar second-of-a-kind projects.[7]) A new pilot-scale natural gas oxy-fuel demonstration began operating at the NET Power facility in Texas in May 2018, and the company is targeting 2022 to commercially deploy a 300-megawatt project using a supercritical CO_2 cycle.[8] The National Carbon Capture Center in Wilsonville, Alabama, is now installing a natural-gas-fired system to test technologies under natural-gas-fired and coal-fired flue gas conditions.[9] And in February 2018, Congress expanded and extended the 45Q tax credit to incentivize greater utilization and storage of captured CO_2.[10]

However, costs must continue to decline, and infrastructure barriers (e.g., availability of CO_2 pipelines and storage infrastructure) must be addressed before CCUS will be viable for full-scale deployment. Several demonstration projects that were designated for federal support under the 2009 Recovery Act were never completed due to cost, scheduling, and other barriers.[11] Even with the 45Q tax credit, current state-of-the-art technologies for capturing and storing carbon emissions are still too expensive to spur widespread deployment in the largest-emitting sectors, particularly power plants and cement and steel production.[12]

DOE's carbon capture program has primarily focused on coal-fired power plants, to the exclusion of natural gas power plants and other industrial sources. The ICCS program, which has explored both power plant and industrial applications of carbon capture, received a one-time appropriation through the American Recovery and Reinvestment Act of 2009 (ARRA), but has received no further funds.[13] This focus leaves the unique challenges of integrating and optimizing carbon capture with other sources of emissions unsolved. The Information Technology and Innovation Foundation (ITIF) recommends DOE establish new carbon capture programs for natural gas power plants and industrial facilities (see box 1).[14] ITIF also calls for the federal government to invest in a robust portfolio of demonstration projects, which would include major investments in CCUS.[15] In FY 2020, Congress for the first time directed DOE to reserve $4 million "for research and optimization of carbon capture technologies for use at industrial facilities," and $7 million for carbon capture at natural gas power plants.[16]

DOE has set the target of reducing the cost of carbon capture to less than $40 per metric ton of CO_2 by 2025—and under $30 per metric ton by 2035.[17] Additionally, DOE has sought to establish international leadership in CCUS technologies through its participation in the Clean Energy Ministerial and Mission Innovation.[18]

The Energy Act of 2020 incorporates many of the recommendations in *Energizing America*, and entails a significant restructuring and expansion of the program. The bill expands research and development (R&D) activities to include power plants and manufacturing and industrial facilities that use coal or natural gas. The bill also creates a new program to conduct large-scale pilot projects at a scale "beyond laboratory development and bench scale testing, but not yet advanced to the point of being tested under real operational conditions at commercial scale."[19] The bill directs DOE to begin six commercial demonstrations of carbon capture by 2025—two each from coal power plants, natural gas power plants, and industrial facilities—and authorizes funding to conduct front-end engineering design (FEED) studies to support the demonstration

projects. Finally, the bill directs DOE to establish one or more Carbon Capture Test Centers, to support large-scale pilot and demonstration projects and test carbon capture technologies.[20]

Figure 1 shows historical DOE investment in carbon capture R&D by subprogram, for FY 2016 through 2021, and the FY 2022 budget request. (Appropriations by subprogram were unspecified for FY 2021, and the top-line number only is shown for that year.) The orange line shows total authorized funding levels in the Energy Act of 2020 for FY 2021 through 2025, across all carbon capture activities. Authorizations across the five new subprograms—carbon capture R&D, large-scale pilots, demonstration projects, FEED studies, and test centers—are shown as transparent bars. The blue line shows recommended R&D (only) funding levels from the *Energizing America* report (see box 1). *Energizing America* also recommends separate funding for large demonstration projects (not shown in figure 1), not broken down across technology or DOE program office.

Box 1: An Innovation Agenda for Carbon Capture

The *Energizing America* report coauthored by the Information Technology and Innovation Foundation (ITIF) and Columbia University's Center on Global Energy Policy offers several recommendations to accelerate carbon capture innovation.[21] ITIF's recent "Build Back Cleaner" report recommends creating a portfolio of carbon capture demonstration projects at industrial facilities such as for cement and steel manufacturing:[22]

- Congress should fully fund the Energy Act of 2020 authorization levels and continue to support the expansion of carbon capture R&D to include natural gas power plants and industrial facilities.
- Congress should provide full funding for technology scale-up activities through large-scale pilot and demonstration projects, FEED studies, and test centers. Congress should pay special attention to industrial carbon capture demonstration projects, including steel and cement manufacturing, wherein other countries have an early lead but where investments now could help the United States reclaim leadership in carbon capture technologies.[23]
- Congress and DOE should address CO_2 infrastructure and regulatory barriers that deter investment in carbon capture. DOE should work with the Department of Transportation, U.S. Geological Survey, and other agencies to plan and assess the requirements for a national CO_2 trunk pipeline network, characterize geologic storage reservoirs, and establish permitting rules.[24]
- Congress should extend the 45Q tax credit for CCUS, making the project fully refundable for projects that commence construction prior to 2022, and raising the credit to $70 per metric ton of CO_2 less the explicit carbon price established.[25]
- DOE should rename the Office of Fossil Energy as the Office of Carbon Management, refocus carbon-reduction and climate-mitigation activities and expand carbon capture research to applications in both the industrial and electricity sectors. This new office should coordinate with other DOE offices with complementary missions (e.g., Advanced Manufacturing Office (AMO) for industrial decarbonization and Bioenergy Technologies Office for bioenergy with carbon capture and storage (CCS)).

Carbon Capture RD&D Activities

RD&D in carbon capture is spread across two activities:

- **Post-Combustion Capture Systems** focuses on separating and capturing CO_2 from flue gas after the fuel has been combusted. These systems can be used to retrofit existing fossil-fuel power plants. Because CO_2 makes up only 3–4 percent of flue gas from natural gas plants and 12–15 percent of flue gas from coal plants, separation is challenging—and once separated, the pure CO_2 must then be compressed for sequestration.[26]

- **Pre-Combustion Capture Systems** focuses on removing CO_2 from fossil fuels before combustion is complete. Coal can be gasified under high pressure to produce a mixture of hydrogen and highly concentrated CO_2, with the former used for energy storage and fuel, and the latter captured and sequestered.

Activities within the carbon capture program are tightly coupled with R&D in advanced energy systems. Solid oxide fuel cells (SOFCs), gasification systems, oxy-combustion and chemical looping combustion, and direct-fired supercritical CO_2 cycles (i.e., Allam cycles) are all designed and optimized to integrate with carbon capture technologies.[27]

Key Elements of the FY 2022 Budget Proposal[28]

The budget proposal seeks $150 million for carbon capture RD&D activities, a 19 percent boost from FY 2021 enacted levels. Some highlights include:

- **An 18 percent increase in Post-Combustion Capture Systems,** including continued support for transformational small-scale and bench-scale carbon capture tests on flue gases from coal and natural gas; continued support for transformational pilot-scale carbon capture projects for industrial CO_2; increased funding to support ten carbon capture FEED studies for industrial and natural gas sources of CO_2; and funding to support the operation of the National Carbon Capture Center (NCCC) test facility.
- **A 20 percent increase in Pre-Combustion Capture Systems,** including increased funding to support carbon capture development and gasification design and component testing for clean hydrogen production.

Further Reading

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ENDNOTES

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