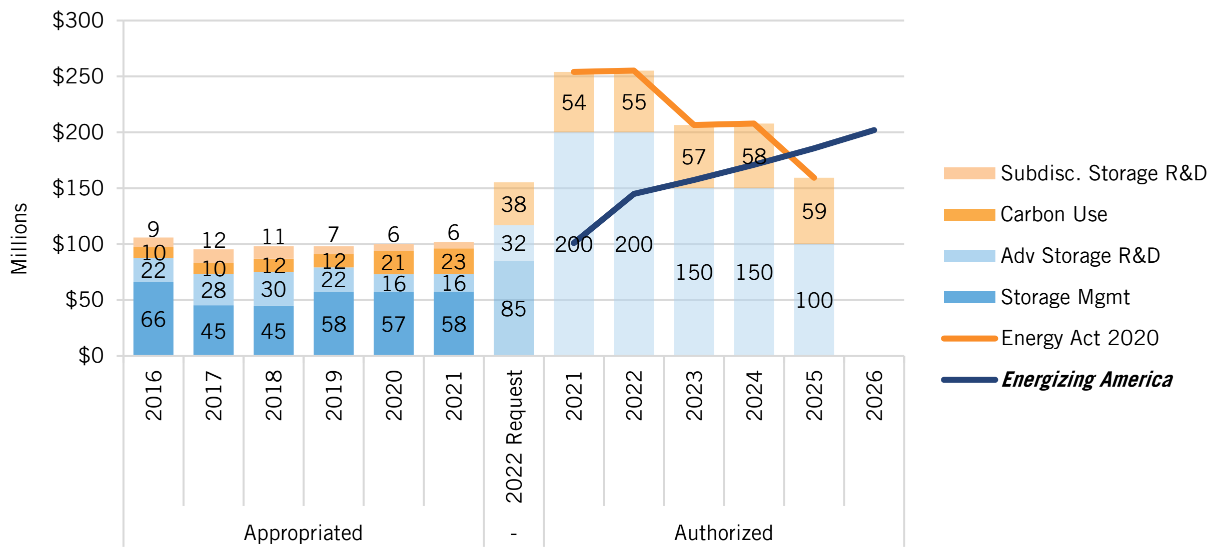
Federal Energy RD&D: Carbon Storage and Utilization

BY COLIN CUNLIFF AND LINH NGUYEN | JUNE 2021

The Carbon Storage and Utilization programs are focused on the development of technologies for the safe use and permanent storage of captured carbon dioxide (CO_2). The storage program focuses on developing the technologies and infrastructure necessary to store captured CO_2 safely in deep saline formations or oil and natural gas reservoirs.[1] The carbon use and reuse program focuses on recycling captured CO_2 for use in valuable products, such as chemicals, fuels, and building materials.

Figure 1: The Energy Act of 2020 authorizes a 150 percent increase in carbon storage and use in FY 2022.[2]



What's at Stake

Limiting global climate change to less than 2°C of warming may require between 20 billion and 60 billion tons of CO_2 to be captured and sequestered every year by the end of the century.[3] If so, carbon management will become one of the world's largest industries, equivalent in scale to food production (~15 billion tons), construction materials (>60 billion tons), and fossil fuel production (~20 billion tons).[4]

Preliminary research suggests the United States has enough subsurface capacity to permanently sequester 1.71 trillion metric tons of CO_2, which is the equivalent of 950 years of carbon emissions from power plants at 2016 levels.[5] However, additional cost reductions, validation, safety testing, and mitigation research are necessary to realize this capacity. While the size of many subsurface storage reservoirs has already been initially characterized, detailed site-specific work is required to confirm their potential. Research and development (R&D) are also needed for tools to map and simulate below-ground fractures and faults with a high degree of resolution and fidelity, devise wellbore materials that can better resist corrosion by CO_2-saturated brine, and improve the ability to monitor and mitigate the risk of induced seismicity from the injection of

CO_2 underground. And large-scale, long-term demonstration projects are necessary to ensure captured CO_2 is safely and permanently stored.

In April 2017, the Illinois Industrial Carbon Capture and Storage project—funded jointly by the Department of Energy (DOE) and private investors—began capturing CO_2 from an ethanol production facility and storing it underground in a saline reservoir at a rate of 1 million metric tons of CO_2 per year. This large, first-of-a-kind demonstration project is testing and validating technologies while concurrently endeavoring to reduce future costs.[6] In 2018, as part of its Carbon Storage Assurance Facility Enterprise (CarbonSAFE) initiative, DOE selected three additional cost-shared research, development, and demonstration (RD&D) projects to identify sites that could store more than 50 million metric tons of CO_2.[7] This effort must be expanded. The National Academies of Sciences, Engineering, and Medicine (NASEM) recommends that DOE work with the Department of Interior and U.S. Geological Survey to "[c]haracterize sustained CO_2 injection rates that can be achieved across each of the major CO_2 sequestration basins and identify by 2030 high injection rate locations suitable for injection of approximately 250 million metric tons of CO_2 per year."[8]

Carbon utilization—turning CO_2 from waste into a product of value—provides another option for managing CO_2 and may be a glide path to incenting greater carbon capture. Most potential uses for captured carbon, such as carbon nanotubes and synthetic hydrocarbon fuels, are far from commercialized and require further RD&D in order to bring costs down. In 2019, the National Academies developed a broad innovation agenda for chemical and biological conversion of CO_2 into fuels and chemicals, but funding at DOE has been insufficient to address the full suite of RD&D that needs to be identified by the study.[9]

The vast majority of captured carbon would ultimately need to be sequestered in geologic reservoirs. Even if carbon use expands substantially, potential markets to absorb CO_2 will be much smaller than the total carbon capture, utilization, and sequestration (CCUS) anticipated in a net-zero emissions world. For example, if CO_2 were used as the source of all carbon in the global annual production of plastics (311 million metric tons per year in 2014), it would consume about 0.8 gigatons of CO_2 per year, far less than 10 percent of the anticipated total previously referenced.[10]

The Energy Act of 2020 provides the first reauthorization of DOE's carbon use and storage program in over a decade. The bill directs DOE to establish a large-scale carbon sequestration demonstration program and requires DOE to produce a roadmap for carbon storage RD&D activities through 2025 to reduce economic and policy barriers to commercial carbon storage.[11] The bill also expands DOE's carbon utilization RD&D program and directs DOE to establish a two-year demonstration program in each of the major coal-producing regions to accelerate commercial deployment of coal-carbon products—such as carbon fiber derived from coal—that result in no significant emissions of CO_2 or other pollutants. The bill directs DOE to establish a national Carbon Utilization Research Center to support early-stage RD&D activities to convert CO_2 into valuable products and commodities.[12]

Figure 1 shows historical DOE investment in carbon utilization and storage activities by subprogram, for FY 2016 through 2021, and the FY 2022 budget request. (Appropriations for carbon storage by subprogram were unspecified for FY 2021, and the topline number only is shown.) The orange line shows total authorized funding levels in the Energy Act of 2020 for FY

2021 through 2025, across all carbon storage and use activities. Authorizations across carbon storage and use are shown as light orange and blue bars. The blue line shows recommended R&D (only) funding levels from the *Energizing America* report (see box 1).

Box 1: An Innovation Agenda for Carbon Storage and Use

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 storage and use innovation.[13]

- DOE should identify the funding levels needed to address the recommendations of the National Academies of Sciences, Engineering, and Medicine's (NASEM) roadmap for advancing CO_2 utilization technologies. Congress should provide sufficient funding to match the RD&D needs.[14]

- DOE should increase the ambition of its current carbon storage goal of 50 million metric tons of storage capacity characterized by 2026 and adopt the National Academies target of 250 million metric tons by 2030. DOE should develop a roadmap and funding levels to meet the new target, and Congress should provide sufficient levels of funding .[15]

- 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.[16]

Carbon Storage and Utilization RD&D Activities

Funding for carbon storage and utilization RD&D is spread across four activities:

- **Storage Infrastructure R&D** focuses on geologic resource characterization and small- and large-scale field projects to demonstrate permanent geologic storage; validation of injection, simulation/risk assessment, and monitoring strategies; and assessment of the probability, and subsequent mitigation, of potential seismic events. Program activities include the CarbonSAFE initiative, which funds industry cost-shared RD&D projects to characterize and develop commercial-scale (more than 50 million metric tons of CO_2) storage complexes by 2025; the Brine Extraction Storage Test, which advances strategies for managing subsurface pressure and fluid flow; and the seven Regional Carbon Sequestration Partnerships (RCSPs), which are currently testing large-scale CO_2 injection and storage technologies.[17]

- **Advanced Storage R&D** is focused on validating storage monitoring, simulation, risk assessment, and advanced wellbore technologies to detect and mitigate wellbore issues. R&D activities include developing CO_2-resistant construction materials and well-integrity technologies, plus technologies to detect and mitigate potential CO_2 leakage pathways.

- **Sub-disciplinary Storage R&D** focuses on assessment and validation of subsurface models; support for the National Risk Assessment Partnership (NRAP), with a focus on storage risk tools; and development of the Energy Data Exchange (EDX) system, which supports data management and technology transfer. The budget request proposes merging the subprogram with Advanced Storage R&D.[18]
- **Carbon Use & Reuse R&D** explores the beneficial reuse of CO_2, including conversion into higher-value products such as chemicals, plastics, and building materials, and accelerated curing for cement. The primary objective is to lower the near-term costs of CCUS through the creation of value-added products via the conversion of CO_2.

Key Elements of the FY 2022 Budget Proposal[19]

The budget proposal seeks $155 million for carbon storage and utilization RD&D activities, a 52 percent boost from FY 2021 enacted levels. Some highlights include:

- **A 48 percent increase in Storage Infrastructure R&D,** including increased funding for the CarbonSAFE initiative to identify opportunities for onshore and offshore storage formations; and increased funding for the four Regional CCUS initiative projects.
- **A 104 percent increase in Advanced Storage R&D (which would be merged with Sub-disciplinary Storage R&D),** to support storage options beyond sedimentary basins and continue to fund the Science-informed Machine learning to Accelerate Real-Time (SMART) Initiative that advances artificial intelligence and machine learning-based technologies to optimize storage operations.
- **A 65 percent increase in Carbon Use & Reuse R&D,** which will support the development of at least one carbon utilization integrated system.

Further Reading

- Varun Sivaram et al., *Energizing America: A Roadmap to Launch a National Energy Innovation Mission* (ITIF and Columbia University SIPA Center on Global Energy Policy, 2020), http://www2.itif.org/2020-energizing-america.pdf.
- National Academies of Sciences, Engineering, and Medicine (NASEM), *Accelerating Decarbonization of the U.S. Energy System* (National Academies Press, 2021), https://doi.org/10.17226/25932.

Acknowledgments

The author wishes to thank David M. Hart for providing input to this report. Any errors or omissions are the authors' alone.

About the Authors

Colin Cunliff is a senior policy analyst for clean energy innovation with ITIF. He previously worked at the U.S. Department of Energy on energy sector resilience and emissions mitigation. He holds a Ph.D. in physics from the University of California, Davis.

Linh Nguyen is a research assistant for clean energy innovation with ITIF. She previously worked for Climate Advisers and Resource Energy. Linh holds a master's degree in energy policy from Johns Hopkins University.

About ITIF

The Information Technology and Innovation Foundation (ITIF) is an independent, nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized by its peers in the think tank community as the global center of excellence for science and technology policy, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

For more information, visit us at www.itif.org.

ENDNOTES

1. U.S. Department of Energy (DOE), "FY 2021 Congressional Budget Justification," Volume 3 Part 2, 233–234, (DOE Chief Financial Officer, DOE/CF-0164, February 2020), https://www.energy.gov/sites/prod/files/2020/02/f72/doe-fy2021-budget-volume-3-part-2_2.pdf.
2. Consolidated Appropriations Act, 2021, Division Z, Title V—Carbon Removal, Sec. 4003, https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf.
3. International Panel on Climate Change (IPCC) (2014b). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, eds O. Edenhofer et al., New York, NY: Cambridge University Press, Cambridge.
4. Phil Renforth and Jennifer Wilcox, "Specialty Grand Challenge: Negative Emissions Technologies," *Frontiers in Climate* (May 21, 2019), https://doi.org/10.3389/fclim.2019.00001.
5. DOE, "Siting and Regulating Carbon Capture, Utilization, and Storage Infrastructure" (Washington, D.C.: DOE Office of Energy Policy and Systems Analysis and Office of Fossil Energy, January 2017), 14, https://www.energy.gov/sites/prod/files/2017/01/f34/Workshop%20Report--Siting%20and%20Regulating%20Carbon%20Capture%2C%20Utilization%20and%20Storage%20Infrastructure.pdf; EPA Draft, "Inventory of U.S. Greenhouse Gas Emissions and Sinks," Table ES-2 (Washington, D.C.: Environmental Protection Agency, February 2018), https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
6. DOE, "DOE Announces Major Milestone Reached for Illinois Industrial CCS Project," accessed March 29, 2019, https://www.energy.gov/fe/articles/doe-announces-major-milestone-reached-illinois-industrial-ccs-project.

7. DOE, "Energy Department Selects Additional Carbon Storage Feasibility Projects to Receive Nearly $30M in Federal Funding," accessed March 29, 2019, https://www.energy.gov/fe/articles/energy-department-selects-additional-carbon-storage-feasibility-projects-receive-nearly.
8. National Academies of Sciences, Engineering, and Medicine (NASEM), *Accelerating Decarbonization of the U.S. Energy System* (Washington, D.C.: The National Academies Press, 2021), https://doi.org/10.17226/25932.
9. NASEM, *Gaseous Carbon Waste Streams Utilization: Status and Research Needs* (Washington, D.C.: The National Academies Press, 2019), https://doi.org/10.17226/25232.
10. Secretary of Energy Advisory Board, "Task Force Report on CO2 Utilization and Negative Emissions Technologies" (SEAB CO_2 utilization Task Force, December 2016), https://www.energy.gov/sites/prod/files/2016/12/f34/SEAB-CO2-TaskForce-FINAL-with%20transmittal%20ltr.pdf.
11. Consolidated Appropriations Act, 2021, Division Z, Title V—Carbon Removal, Sec. 4003, https://rules.house.gov/sites/democrats.rules.house.gov/files/BILLS-116HR133SA-RCP-116-68.pdf.
12. Ibid.
13. Varun Sivaram et al., *Energizing America: A Roadmap to Launch a National Energy Innovation Mission* (ITIF and Columbia University Center on Global Energy Policy, 2020), https://itif.org/publications/2020/09/15/energizing-america-roadmap-launch-national-energy-innovation-mission.
14. NASEM, *Gaseous Carbon Waste Streams Utilization: Status and Research Needs* (Washington, D.C.: The National Academies Press, 2019), https://doi.org/10.17226/25232.
15. NASEM, *Accelerating Decarbonization of the U.S. Energy System*, 57.
16. NASEM, *Accelerating Decarbonization of the U.S. Energy System* (National Academies Press, 2021), https://doi.org/10.17226/25932.
17. DOE, "Storage Infrastructure," accessed March 29, 2019, https://www.energy.gov/fe/storage-infrastructure.
18. DOE, "FY 2018 Congressional Budget Justification," Volume 3, 369–372 (DOE/CF-0130, May 2017). The FY 2021 budget request proposes restructuring the carbon storage projects, so definitions from an earlier fiscal year are used here.
19. DOE, "FY 2022 Congressional Budget Justification" Volume 3.2, (DOE Chief Financial Officer DOE/CF-0174, May 2021), 216-222, https://www.energy.gov/sites/default/files/2021-06/doe-fy2022-budget-volume-3.2-v3.pdf.