U.S. DEPARTMENT OF ENERGY | Fossil Energy

Direct Air Capture Research and Development Efforts

The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) is a global leader in the advancement of research and technologies for carbon capture, utilization, and storage (CCUS). CCUS is a critical technology that is necessary to mitigate carbon dioxide (CO_2) emissions from the power and industrial sectors.

DOE has been actively developing these technologies for over two decades, and has invested over $4 billion in CCUS research, development, and demonstration (RD&D) activities. FE is working with its industry partners, national laboratories, and academia on a wide range of CCUS technologies—including direct air capture (DAC) technologies—to help them become a viable option for reducing CO_2 in the atmosphere.

What is DAC?

DAC is a process that separates CO_2 from ambient air. The separated CO_2 can then be safely and permanently stored underground; used for enhanced oil recovery; or converted into value-added products. By accelerating the deployment of this indispensable technology, the United States can continue gaining energy independence while reducing carbon emissions.

Current DAC Research Activities (2018–2020)

DOE is currently investing in several research and development (R&D) projects for DAC and the results of these projects are helping to shape DOE's future R&D plans in this area. For example, the National Academies of Sciences (NAS), supported by DOE, completed a review of the existing science and technologies and recommended a research agenda for DAC technologies.

To date, DOE has invested $1 billion in the development of systems and technologies for point-source capture—a method of collecting CO_2 directly from power plants—that FE is leveraging to accelerate the development of DAC processes. For example, over $250 million has been invested in the National Carbon Capture Center (NCCC), a user facility that hosts developers of carbon capture technologies, who research from the laboratory all the way to the small-pilot level. Over 80 engineers and scientists support project testing at the NCCC and are available to support the validation of DAC systems and technologies. This billion-dollar investment does not include major CCUS demonstration projects such as NRG Energy's Petra Nova Project in Texas and the Lake Charles project in Louisiana.

Image: National Carbon Capture Center

Additionally, FE is exploring new strategies which aim to reduce the overall cost of DAC systems, including additive manufacturing.

DOE's current R&D activities include the following:

- **Workshop for DAC R&D Priorities (2019)**: United States Energy Association and FE co-sponsored workshop with 50+ experts to seek input on the R&D program plan for DAC.
- **Techno Economic Assessment (TEA) (2020)**: Techno-economic analyses of the Carbon Engineering pilot plant to establish a cost baseline for DAC.
- **National Resources Assessment (2020)**: Complete national resource assessment identifying regions and markets to target areas with high CO_2 prices, underutilized energy sources, and the lack of CO_2 transportation infrastructure, to support a sustainable business model for DAC.
- **DAC Sponsored Projects (2018–2020)**: Three projects specifically designed for low-concentration capture (solvent, sorbent, and membrane systems) are being sponsored:

- *Carbon Engineering, Ltd*. is validating the small-scale air capture systems to recapture legacy emissions. Learn more on the National Energy Technology Laboratory's (NETL) website here.
- *Ohio State University* is developing cost-effective design and manufacturing processes for new membranes and membrane modules that capture CO_2 from less than 1% CO_2 concentration sources. Learn more on NETL's website here.
- *InnoSepra LLC* is developing a low-cost, sorbent-based process for the capture of CO_2 from low-concentration feed streams. Learn more on NETL's website here.

Future DAC Research Activities (2021–2034)

In addition to the above, the NAS research agenda made recommendations regarding DAC R&D activities that DOE will pursue. The dates and timeline included below are a part of a plan DOE is considering to develop and scale second-generation DAC technologies to make the most efficient use of the existing R&D CCUS program activities and infrastructure, such as the NCCC.

- **Parallel R&D on DAC Materials, System Components, and Process Design (2019-2024):**
  - *Materials and Laboratory Development*: Computer simulation in order to identify new materials specific to DAC. Materials synthesis efforts to scale up novel materials, which are often available only in very small quantities (e.g., scale up to kilogram scale can be cost-prohibitive).
  - *Process Components*: System components and equipment designs capable of more efficient mass and thermal transport (e.g., heat exchangers, contactors, regenerators, monoliths, compressors, and pumps) that achieve more effective and/or integrated unit operations (e.g., process intensification) are of interest.
  - *Optimized System Design*: Development (e.g., design, construction, and testing) of integrated bench-scale systems greater than 100 kilograms per day should be supported. This includes integrated systems to optimize power consumption, cycling to follow grid prices, hybrid concepts, waste heat integration, and alternative schemes such as cryogenic.
- **Pilot-Scale Tests (2025-2029)**: These tests are necessary to integrate advanced materials and process intensification into a functional system at a small-pilot scale.
- **Front End Engineering and Design (2027-2030)**: These novel systems should be developed, analyzed from a system perspective, and subjected to third-party review to determine more accurate cost estimates, which include the project developer design criteria to support commercial demonstration facilities.
- **Large-Scale, Extended Tests (2030-2034)**: The most significant barrier limiting the assessment and deployment of manufactured DAC processes is the absence of process-scale operational data that is needed for accurate techno-economic analyses. R&D programs must support this aspect to demonstrate potential cost reductions and performance improvements.

DAC Research Challenges

Many of the technologies and systems developed for point-source capture may be translated to DAC; however, the technologies must address issues such as scaling and diluted feedstocks. DAC could benefit from improvements to gas separation materials, process optimization, incorporation with local conditions, and integration with industrial sources for waste heat; all of which can help reduce DAC costs and operational expenses. A NAS report indicated that the current estimated cost of DAC ranges from $200 to $1,000 per tonne of CO_2 removed.

FE will help scale the technology necessary to leverage the existing research and development so that DAC can ultimately be brought to a commercial CO_2 market. Learn more about Fossil Energy and its CCUS research here.