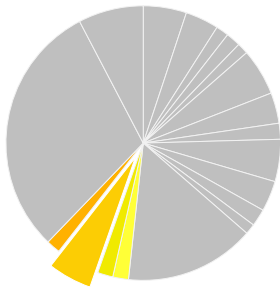




Federal Energy R&D: Advanced Coal Energy Systems

BY COLIN CUNLIFF AND BATT ODGEREL | MARCH 2020

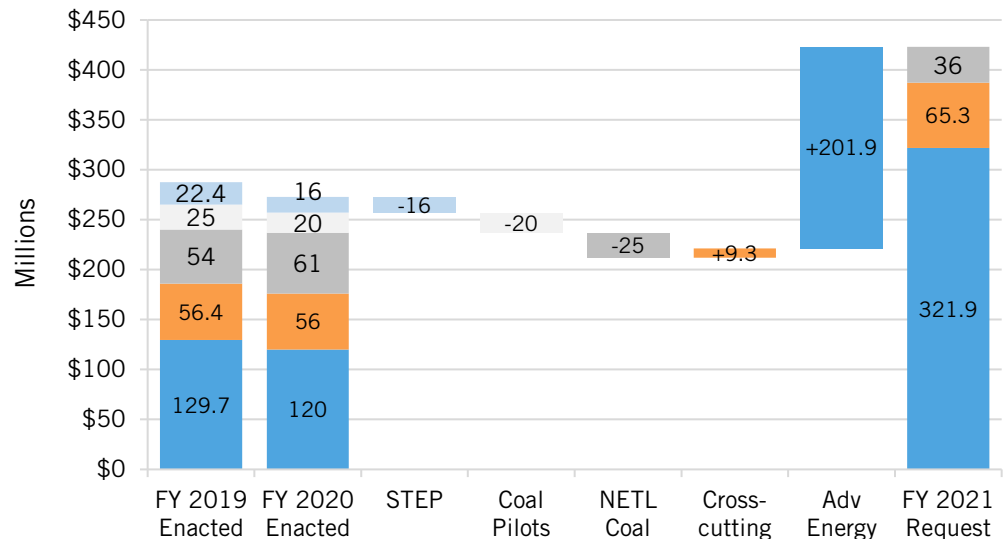
This briefing is part of a series on the U.S. energy budget. See: itif.org/energy-budget.



Adv Coal (orange)
Other Fossil (yellow)
Energy R&D (gray)

The Department of Energy’s (DOE) Advanced Coal Energy Systems research and development (R&D) program focuses on improving the efficiency of coal-based power systems, developing advanced technologies such as gasification and fuel-cell systems, improving environmental mitigation of coal power, and enhancing the value of coal and coal by-products.¹

Figure 1: The FY 2021 budget request would increase Advanced Coal Energy Systems R&D by 68 percent²



What's at Stake

Coal currently accounts for 24 percent of U.S. electricity generation and 60 percent of power-sector carbon emissions.³ Coal-fired generation is projected to decline through the mid-2020s, although it is projected to remain a significant part of the nation’s energy mix for decades to come.⁴

Some Advanced Coal Energy Systems R&D projects are designed and intended to integrate with carbon capture technologies, which would enable the continued use of coal in low-carbon energy systems. For example, gasification systems combine coal with oxygen and steam under high pressure to produce a hydrogen and carbon dioxide (CO₂) gas mixture. The CO₂ can be separated prior to combustion, and the remaining hydrogen combusted in a combined-cycle power plant.⁵ Similarly, solid oxide fuel cells (SOFCs) convert gasified coal into electricity without combustion, and produce highly concentrated CO₂ streams

that enable low-cost carbon capture.⁶ Additional research, development, and demonstration (RD&D) of SOFCs and gasification systems integrated with carbon capture is necessary to lower costs and sufficiently improve performance to enable commercial deployment. But these programs are targeted for the largest cuts.

The bulk of funding in the Advanced Coal Energy Systems programs supports the administration's Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) initiative to improve the economics of coal-fired electricity generation and develop the next generation of high-efficiency coal plants. In February 2020, DOE announced \$64 million in federal funding for R&D to develop advanced combustion technologies, supercritical CO₂ systems, and other coal technologies.⁷ But without integration with carbon capture, utilization, and storage (CCUS), efficiency improvements alone will not be sufficient to achieve deep emissions reductions from coal-fired power plants.

Advanced Coal Energy Systems Subprograms

Advanced Coal Energy Systems R&D is spread across five subprograms:⁸

- **Advanced Energy Systems** focuses on improving the efficiency of coal-based power systems, and supports research across seven areas: gasification, which converts coal into synthesis gas, chemicals, hydrogen, and liquid fuels (and complements pre-combustion carbon capture R&D); solid oxide fuel cells, which can convert synthesis gas and other fuels into electricity without combustion or emissions; advanced turbines; advanced sensors and controls; power-generation efficiency; advanced energy materials; and coal processing.
- **Cross-Cutting Research** serves as a bridge between basic and applied research by targeting the concepts with the greatest potential for transformational breakthroughs. Current research focuses on these primary activities: improved water management in power plant operations; recovery of rare earth elements as a byproduct of coal production and use; and modeling, simulation, and analysis of environmental and regulatory impacts.
- **Supercritical Transformational Electric Power (STEP)** is a 10-megawatt (MW) pilot-scale demonstration of a Brayton cycle energy conversion system, which uses supercritical CO₂ rather than the traditional steam/water Rankine cycle to convert heat to electricity. Supercritical CO₂ cycles have higher thermal efficiencies and applications for nuclear, gas, and concentrating solar as well as coal power plants.⁹
- **Transformational Coal Pilots** provides funding for the design, construction, and operational costs of two large-scale pilot projects for transformational coal technologies, including pressurized oxygen combustion and chemical looping, and improvements in carbon capture systems.¹⁰
- **NETL Coal R&D** funds all National Energy Technology Laboratory (NETL) in-house research efforts, including the Fossil Energy Roadmap and the NETL Science & Technology competency assessments.

Key Elements of the FY 2021 Budget Proposal¹¹

- **Continues the administration’s Coal FIRST (Flexible, Innovative, Resilient, Small, Transformative) initiative to advance new coal power plant designs** that are small (50 to 350 MW), efficient (40 percent or more thermal efficiency), capable of ramping, and have emissions less than or equal to natural gas plants.
- **A 168-percent increase in Advanced Energy Systems**, with \$182.5 million in increased funding for power-generation efficiency to support the Coal FIRST initiative; and a \$20 million increase to support advanced coal processing to convert coal to carbon fiber, nanomaterials, building materials, and other value-added products. Funding for advanced sensors and controls and advanced energy materials would receive small increases. Funding for advanced turbines, gasification systems, and solid oxide fuel cells would be cut by 66 percent.
- **A 17-percent increase in Cross-Cutting Research**, including increased funding for R&D to support critical and rare-earth minerals extraction from coal and coal waste products; increased funding for modeling and simulation to optimize coal power plants; decreased funding for water management R&D field testing; and reduced funding for university training and research.
- **No new funding for the Transformational Coal Pilots program.** The Consolidated Appropriations Act of 2017 provided \$50 million for new coal pilots to remain available until expended, and the remainder of FY 2020 funding will be used for at least one Phase III construction/operation award.
- **A discontinuation of funding for STEP**, as prior-year appropriations have fully funded the STEP pilot’s CO₂ test facility, now under construction in San Antonio, Texas—and the administration has not announced any plans for follow-on work.
- **A small decrease to NETL Coal R&D.** The \$23 million research activity on rare-earth elements recovery from coal by-products would be moved to the Cross-Cutting Research subprogram, but would not be eliminated. The remaining NETL Coal R&D subprogram would receive a small \$2 million cut, reflecting a deferral of research equipment purchase.

ENDNOTES

1. U.S. Department of Energy (DOE) is proposing to restructure its R&D programs within the CCS and Power Systems account to a new structure that “improves the alignment of the budget structure to the research focus areas...” Here, the term “Advanced Coal Energy Systems” refers to the programs in the new budget structure, minus the carbon capture, utilization, and storage (CCUS) programs. DOE, “FY 2021 Congressional Budget Justification,” Volume 3 Part 2, 207–244 (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. DOE, “FY 2021 Congressional Budget Justification,” Volume 3 Part 2, 207–244.
3. U.S. Energy Information Administration (EIA), “Monthly Energy Review,” Tables 7.2a and 11.6 (EIA, January 28, 2020), accessed February 5, 2020, <http://www.eia.gov/mer>.
4. EIA, “Annual Energy Outlook 2020,” 62, accessed February 5, 2020, <http://www.eia.gov/aeo>.
5. DOE, “Pre-Combustion Carbon Capture Research,” accessed March 23, 2020, <https://www.energy.gov/fe/science-innovation/carbon-capture-and-storage-research/carbon-capture-rd/pre-combustion-carbon>.
6. National Energy Technology Laboratory (NETL), “Solid Oxide Fuel Cell,” accessed February 20, 2020, <https://www.netl.doe.gov/coal/fuel-cells>.
7. DOE, “U.S. Department of Energy Announces \$64M for Components of Coal FIRST Power Plants,” accessed March 13, 2020, <https://www.energy.gov/articles/us-department-energy-announces-64m-components-coal-first-power-plants>.
8. DOE, “FY 2021 Congressional Budget Justification,” Volume 3 Part 2, 207–244.
9. DOE, “DOE Announces \$80 Million Investment to Build Supercritical Carbon Dioxide Pilot Plant Test Facility” (Washington, D.C.: October 17, 2016), <https://www.energy.gov/articles/doe-announces-80-million-investment-build-supercritical-carbon-dioxide-pilot-plant-test>; Southwest Research Institute, “SwRI, GTI, and GE Break Ground on \$119 Million Supercritical CO2 Pilot Power Plant” (October 15, 2018), <https://www.swri.org/press-release/swri-gti-ge-supercritical-CO2-pilot-power-plant>.
10. DOE, “Department of Energy to Invest \$6.5 Million for Large-Scale Pilot Fossil Fuel Projects,” (DOE, February 15, 2018), accessed April 1, 2019, <https://www.energy.gov/articles/department-energy-invest-65-million-large-scale-pilot-fossil-fuel-projects>.
11. DOE, “FY 2021 Congressional Budget Justification,” Volume 3 Part 2, 207–244; DOE, “Energy Department Announces Intent to Fund Research that Advances the Coal Plants of the Future” (DOE, November 13, 2018), accessed April 1, 2019, <https://www.energy.gov/fe/articles/energy-department-announces-intent-fund-research-advances-coal-plants-future>.

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