



Changes in the U.S. electricity industry are forcing a paradigm shift in how the Nation’s generating assets operate. Traditionally, coal-fired power plants operated continuously to meet an established minimum level of demand and were not designed for rapid changes in power output. Today, these coal-fired power plants are increasingly relied on to supplement electricity from intermittent renewable sources, offset variable natural gas demand and supply, and deliver critical ancillary services to the grid.

## Flexible, Innovative, Resilient, Small, Transformative

The U.S. Department of Energy’s (DOE) Office of Fossil Energy (FE) is funding **Coal FIRST** (Flexible, Innovative, Resilient, Small, Transformative), a research and development (R&D) program to advance first-of-a-kind carbon neutral or net-negative greenhouse gas (GHG) emissions coal generation technologies to provide secure, stable, and reliable power.

The Coal FIRST program will help develop 21st century coal-fired power plants that are:

- **Flexible:** quick to adjust to the changing needs of the grid
- **Innovative:** cleaner, more agile, and more efficient through cutting-edge technology
- **Resilient:** able to recover rapidly from severe weather and other events
- **Small:** compact, relative to today’s conventional utility-scale coal plants
- **Transformative:** fundamentally redesigned to meet emerging and future grid needs



## The Future Coal Fleet

The need for considerable dispatchable generation, critical ancillary services, and grid reliability—combined with potentially higher future natural gas prices and energy security concerns, such as onsite fuel availability during extreme weather events—creates the opportunity for advanced coal-fired generation in domestic and international markets.

Deploying new coal plants will require a different way of thinking. To that end, DOE envisions that the future coal fleet may be based on electricity generating units possessing the following traits:

- Carbon neutral with the possibility of net-negative carbon dioxide (CO<sub>2</sub>) emissions
- Capable of producing power and hydrogen for polygeneration
- Feedstock flexibility; utilizing coal while co-firing biomass and waste plastics
- Integration with thermal or other energy storage to mitigate inefficiencies and equipment damage
- High overall efficiency (40%+) over most of the generation range
- Small, high-quality, low-cost units (50 MW to 350 MW) that minimize field construction time
- Ramp rates (>4%/min) and minimum loads (<20%) compatible with 2050 estimates of renewable energy integration
- Minimized water consumption
- Accelerated design, construction, and commissioning schedules
- Enhanced maintenance features, including advanced monitoring and diagnostics to reduce downtime
- Integration with coal upgrading or other plant value streams (e.g., co-production)

Additionally, an export opportunity for Coal FIRST technologies exists, especially in developing countries. Technologies promoted by this initiative have the potential to improve a country’s energy security, and in many cases, to expand energy access for those who live without electricity by enabling them to use indigenous fuels. Coal FIRST

technologies will also enhance U.S. advantages as a coal supplier for domestic and international markets.

## Main Activity Areas

### Design of a Power Plant of the Future

As Phase 1 of a 2018 request for proposal, the Coal FIRST program evaluated 13 responses for concepts and selected the seven shown below for coal-based power plants of the future:

- Small-scale flexible AUSC power plant, *Electric Power Research Institute*
- PFBC for modular coal power, *CONSOL*
- USC coal boiler downstream of NG turbine, *Barr Engineering Co.*
- Coal-fired Allam cycle, *8 Rivers Capital, LLC*
- Direct injection carbon engine and gas turbine compound-reheat combined cycle, *Nexant, Inc.*
- PFBC for indirect sCO<sub>2</sub> cycle, *Echogen Power Systems (DE)*
- Gasification-based polygen with bottoming cycle, *Allegheny Science & Technology*

In a second phase, preliminary front end engineering and design (pre-FEED) studies were completed in May 2020. In March 2020, the first funding opportunity announcement (FOA), "Critical Components for Coal FIRST Power Plants of the Future" (DE-FOA-0002057) was issued. The critical components identified from the pre-FEED studies as well as from the PROVISIO program were selected for R&D to enhance critical technology features for the related power generation technologies. The following preliminary concepts were identified in the FOA:

- Pressurized Fluidized Bed Combustor with Supercritical Steam Cycle Power Plant System
- Indirect Supercritical Carbon Dioxide Power Plant System
- Direct-fired Supercritical Carbon Dioxide Power Plant System
- Gasification-Based Poly-generation (for power and other products, such as NH<sub>3</sub>)
- Coal-Fired Direct Injection Combustion Engine & Gas Turbine Compound Reheat Combined Cycle Power Plant System

- Modular Staged Pressurized Oxy-combustion Power Plant System
- Flameless Pressurized Oxy-combustion Power Plant System

The awards will be made during the fourth quarter of 2020.

A draft FOA on the "Design Development and System Integration for Coal FIRST Concepts" was issued in May 2020 (DE-FOA-0002180). The comments received on this FOA will be incorporated into the final FOA, which will be issued during the third quarter of 2020. The awards will be made during the last quarter of 2020 or the first quarter of 2021. The awards will be in the following four categories:

1. Flexible Ultra Supercritical (USC) Coal-Fired Power Plant
2. Pressurized Fluidized Bed Combustor with Supercritical Steam Cycle Power Plant
3. Hybrid Natural Gas Turbine / USC Coal Boiler Power Plant
4. Flexible Gasification of Coal and Biomass to Generate Electric Power and a Carbon-Free Hydrogen Co-Product

### Existing Plant Efficiency Improvement Demonstrations

To ensure that efficiency improvements can be incorporated into the Power Plant of the Future, DOE issued FOA-1989 in December 2018 to support R&D for various areas of existing coal power plants. DOE awarded a total of 17 projects under this FOA in October 2019. These projects relate to thermal energy storage, coating to enhance life, sensors and control, predictive maintenance, and artificial intelligence to increase stable operation and efficiency, along with load following. The results of these projects will be incorporated into the Power Plant of the Future FEED studies.

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