# Advanced Energy Systems

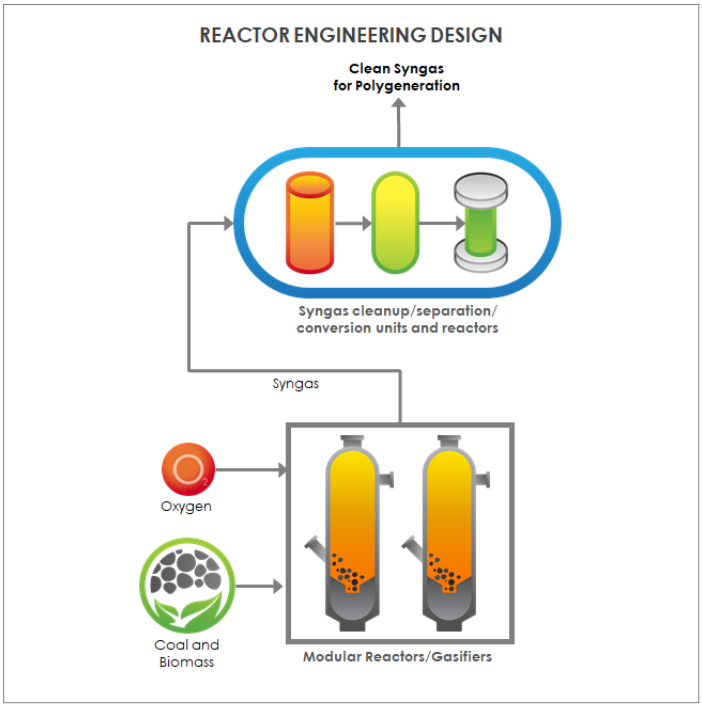
The Advanced Energy Systems (AES) program, under the Office of the Clean Coal and Carbon Management's research and development (R&D) portfolio, is developing a new generation of clean coal-fueled energy technologies capable of producing competitively priced electric power while reducing carbon dioxide ($CO_2$) emissions. The focus is on improving efficiency, increasing plant availability, reducing water consumption, and achieving ultra-low emissions of traditional pollutants. Much of this research is targeted at improving overall system efficiency, reducing capital and operating costs, and enabling affordable carbon capture.

By leveraging advances in technology, the U.S. Department of Energy (DOE) can meet the challenges facing coal power plants, such as the increased cycling of these plants. DOE can also represent and expand U.S. markets focused on technology development that can enable the coal plant of the future to respond to emerging issues and opportunities, such as improved efficiency and reduced emissions.

The AES program develops innovative, carbon neutral or net-negative greenhouse gas (GHG) emissions technologies that integrate with carbon capture and storage (CCS) capabilities and improved fuel conversion efficiency. The R&D portfolio includes gasification, advanced turbines, solid oxide fuel cells, coal and coal by-products, sensors and controls, extreme environment materials, water management, and innovative energy concepts.

The **Coal FIRST** (Flexible, Innovative, Resilient, Small, Transformative) initiative is developing energy plants of the 21st century, which produce electricity, hydrogen, or both. They will be carbon-neutral or even have net-negative $CO_2$ emissions. This initiative is a top priority for the Office of Clean Coal and Carbon Management.

A description of each AES program follows:




## Gasification Systems

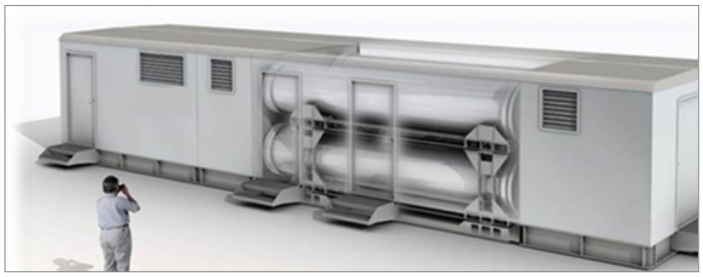
The Gasification Systems R&D focuses on developing small-scale revolutionary modular designs for converting diverse types of coal into clean synthesis gas to enable the low cost production of electricity, high-value chemicals, hydrogen, transportation fuels, and other useful products to suit market needs. Advancements in this area will help enable advanced power generation and other syngas-based technologies to be competitive in both domestic and international markets and spur on the use of abundant domestic coal resources. That will increase energy security and revive depressed markets in traditional coal-producing regions of the United States.

Syngas derived from most high pressure gasification processes already contains a significant amount of hydrogen ($H_2$), which can be increased through water gas shift (WGS) and be readily separated into a pure $H_2$ product, meeting industry product quality standards. There are several conventional $H_2$ separation processes, but modern installations preferentially choose pressure swing adsorption (PSA), which is a well-proven technology offering high availability and low cost. PSA has the ability to produce high purity (99.9 percent) hydrogen at near feed pressure; however, relatively high $H_2$ concentration in feed gases is required for the economics to remain favorable. New technologies are being developed to increase the efficiency and reduce the costs associated with $H_2$ production from coal gasification.

## Advanced Turbines

The Advanced Turbines program manages a research, development, and demonstration portfolio designed to remove environmental concerns about the future use of fossil fuels by developing revolutionary, near-zero emissions advanced turbine technologies. In response to the Nation's increasing power supply challenges, DOE is researching next-generation turbine technologies with the goal of producing reliable, affordable, diverse, and environmentally friendly energy supplies. The program and project emphasis is on understanding the underlying factors affecting combustion, aerodynamics/heat transfer, and materials for advanced turbines and turbine-based power cycles.

Advancing hydrogen turbine performance in integrated gasification combined cycle power plants offers the most significant near-term performance benefit for reducing emissions and cost while increasing efficiency. The ultimate goal of the Hydrogen Turbines program is to facilitate the development of advanced components and technology for turbines that provide tangible benefits to the public: lower cost of electricity, reduced emissions of criteria pollutants, and carbon capture options.



## Solid Oxide Fuel Cells

The Solid Oxide Fuel Cells portfolio focuses on the development of low-cost SOFC power generation systems that produce electric power from coal or natural gas with intrinsic carbon capture capabilities. SOFC power systems have the potential to achieve greater than 60 percent efficiency and more than 97 percent carbon capture at a cost-of-electricity projected to be 40 percent below presently available integrated gasification combined cycle systems equipped with carbon capture. The SOFC's operating temperature (less than 1650°F) is lower than combustion-based processes and precludes NOx formation, and there are near-zero emissions of $CO_2$, criteria pollutants, and particulates. Furthermore, SOFC power systems require approximately one-third the amount of water utilized by conventional combustion-based power systems.

A fuel cell converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen-containing fuel with oxygen. The highly efficient fuel cell process emits virtually no pollutants because of the absence of combustion. The modular nature of the fuel cell shows promise for enabling clean, distributed power generation.


## Coal and Coal By-Products

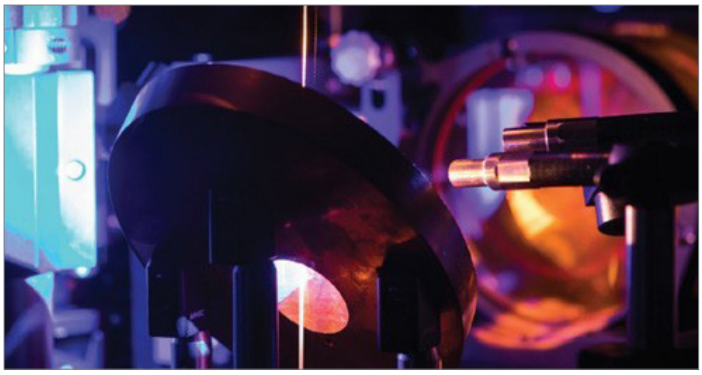
DOE's Office of Fossil Energy and the National Energy Technology Laboratory's Carbon Ore (Coal) to Products program focuses on enhancing the value of carbon ore as a feedstock and developing new high-value products derived from carbon ore.

Research includes testing of laboratory- and pilot-scale technologies to produce upgraded carbon ore feedstocks and additional revenue-producing products. Expanding existing coal property databases assists research efforts and informs potential consumers in domestic global markets. The U.S. coal value chain can be extended by manufacturing carbon products directly from coal instead of using petrochemical or biomass feedstocks and by expanding markets for existing coal products.

## Sensors & Controls R&D

Sensors & Controls R&D makes new classes of sensors and measurement tools that manage complexity, lowers costs, and enables robust monitoring and real-time optimization of fully integrated, highly efficient power generation systems.

Controls research centers use self-organizing information networks and distributed intelligence for process control. The networking of sensors and the use of improved decision-making capabilities promote the reliability of these systems.



## Extreme Environment Materials

Extreme Environment Materials research focuses on structural and functional materials that will lower the cost and improve the performance of fossil-based power generation systems. It incorporates computational tools to support predictive performance, failure mechanisms, and molecular design of materials. The program develops advanced manufacturing technologies to economically fabricate components that cannot be made using conventional techniques.

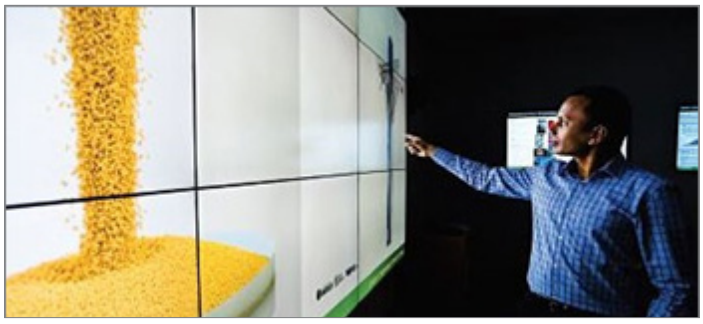
## Water Management

Water Management R&D addresses the need to reduce the amount of fresh water used by power plants and the need to minimize any potential impacts of plant operations on water quality. This can be accomplished through a variety of means including efficiency gains, improvements in water recovery and reuse, and the use of alternate feed sources. The effort requires crosscutting research

directed at ensuring sustainable, efficient water and energy use; developing technology solutions; and enhancing understanding of the intimate relationship between energy and water resources.

## Innovative Energy Concepts

Innovative Energy Concepts research centers focus on the development of innovative cost-effective technologies that enhance the efficiency, environmental performance, and availability of advanced energy systems. It aims to create computational tools that shorten the development timelines of those systems. This area conducts fundamental and applied research in innovative concepts with a 10- to 25- year developmental horizon. The concepts offer the potential for technical breakthroughs and step-change improvements in coal power systems with carbon capture and storage. They minimize the environmental impacts from fossil energy-based power systems.



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