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Enabling Turbine Technologies for Hydrogen Fuels

Turbine Program Advances Ultra-Clean, Coal-Based Systems

Washington, DC — The Department of Energy's Office of Fossil Energy Turbine Technology R&D Program was recently expanded with the selection of 10 new projects valued at $130 million. The new program will advance turbines and turbine subsystems for integrated gasification combined cycle (IGCC) power plants, and address the use of hydrogen in small-scale turbines for industrial applications. Resulting technologies will operate cleanly and efficiently when fueled with coal-derived hydrogen or synthesis gas.

Turbines can generate electrical power on a large scale—in central power stations sized 250 megawatts and larger—or on a small scale—in local, industrial power systems sized 1–100 megawatts. Small-scale systems also produce mechanical power for jet engines, compressors, heating systems, and other applications.

Investing in research that applies new fuels to large- and small-scale turbines provides opportunities for developing a future hydrogen economy, in which hydrogen is the fuel of choice for transportation and power generation. It also maximizes the use of coal, America's most abundant fossil fuel.

A primary focus of this new effort is the integration of hydrogen turbines and turbine subsystems into IGCC central power stations. IGCC is today's environmentally preferred source of electricity from coal and the primary technology component of FutureGen, the Energy Department's planned near-zero-emissions power plant. The use of hydrogen fuels in IGCC systems will reduce emissions—particularly carbon dioxide (CO2), a leading greenhouse gas, and nitrogen oxides (NOx), a pollutant that contributes to ozone production and acid rain—and enable systems to be adapted to a variety of environments.

In addition to the large-scale IGCC applications being explored, several projects will develop 1–100 megawatt-scale systems that can be fueled by either hydrogen or coal synthesis gas (syngas). Advanced technologies in this area will help industry adopt hydrogen as an everyday fuel.

The new projects, described below, will be managed by the Office of Fossil Energy's National Energy Technology Laboratory.

Hydrogen Turbines for FutureGen

Two projects will expand on state-of-the-art, natural gas turbine technologies to design large-scale turbines that burn hydrogen fuels. Performance goals include the capability to integrate the new systems into the Department of Energy's FutureGen power plant or similar IGCC power stations, fuel flexibility for operation on hydrogen and coal syngas, NOX emissions of less than 3 parts per million, and efficiencies of 45–50 percent.

- **General Electric** will advance combustion technologies for hydrogen fuels to achieve the same type of emissions improvement that have been accomplished for natural gas-fueled turbines. Advances will include system materials and coatings able to withstand increased operating temperatures and system designs that increase efficiency and power output. The project will culminate in an engineering design for full-scale testing of a large-frame turbine that achieves an efficiency increase of 3–5 percentage points over current coal-powered turbine technologies. (DOE award: $45.6 million; project duration: 75 months)

- **Siemens Westinghouse Power Corporation** will design an advanced coal-powered turbine system that employs newly designed system components for improved performance. Newly designed components will include an enhanced cooling subsystem for controlling operating temperatures, increased front-end temperatures for more efficient fuel consumption, and advanced materials and coatings for component durability and reduced operating costs. (DOE award: $45.5 million; project duration: 56 months)

Turbines and Combustors for Oxy-fuel Rankine Cycle Systems

Studies indicate that replacing air with nearly pure oxygen in a turbine's combustion chamber is a promising approach to achieving highly efficient, near-zero-emission coal-based power systems. Two projects will develop turbine and combustor technologies that use pure oxygen in fuel combustion. These technologies will be conducive to 100 percent separation and capture of CO2 and will achieve long-term power system efficiencies of 50–60 percent.

- **Siemens Westinghouse Power Corporation** will combine current steam and gas turbine technologies to design an optimized turbine that uses oxygen with coal-derived hydrogen fuels in the combustion process. In this break-through project, system studies will show how this totally new turbine can be integrated into a highly efficient, near-zero-emission power plant. (DOE award: $14.5 million; project duration: 56 months)
- **Clean Energy Systems** will develop and demonstrate a new combustor technology powered by coal syngas and oxygen. The project team will evaluate and redesign the combustion sequence to achieve the ideal ratio of oxygen to fuel, a critical parameter in achieving optimum combustion and reducing costs. (DOE award: $4.5 million; project duration: 39 months)

Development of Highly Efficient Zero-Emission Hydrogen Combustion Technology for Megawatt-Scale Turbines

Two projects will develop hydrogen combustion systems that can be installed in existing megawatt-scale turbines. Turbines using these combustion systems will maintain or exceed the levels of efficiency achieved by similar natural-gas-powered turbines, reduce emissions of NOx, virtually eliminate emissions of CO2, and operate on hydrogen and coal synthesis gas. Systems will be sized at 100 megawatts or less and be fit for mechanical power applications.

- **Precision Combustion, Inc.**, will build and demonstrate a full-scale, ultra-low NOx catalytic combustion system for fuel-flexible hydrogen combustors in megawatt-scale turbines. In a current DOE project, this technology has demonstrated single-digit NOx emissions in small-scale testing with syngas and hydrogen diluted with nitrogen. (DOE award: $4.9 million; project duration: 60 months)
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Parker Hannifin Corporation will adapt the designs and concepts of proven natural gas fuel-injector systems to hydrogen and coal syngas systems. Parker will build and test next-generation fuel burners in a range of sizes. The modularity of this approach will reduce system production costs by allowing the building of injectors to multiple scales from a basic building block. (DOE award: $1.2 million; project duration: 32 months)

Megawatt-Scale Turbines for Power and Hydrogen Co-production in Industrial Applications

One project will assess the potential for industrial, coal-fueled turbine systems to co-produce electricity, hydrogen, and synthesis gas. The evaluation will be conducted with gasification systems in the 50–100 megawatt range and will demonstrate high efficiency and ultra-low emissions at a reduced cost. Results are expected to benefit several U.S. heavy commercial industries.

- The **Gas Technology Institute** will conduct a detailed assessment of the feasibility, opportunities, and challenges of using partial-oxidation gas turbines for the coal-based co-production of electricity, hydrogen, and synthesis gas. In partial-oxidation turbines, part of the system's fuel is unspent during combustion, making it available for post-system use, such as hydrogen extraction. Successful application of the technology would benefit the steel, forest, paper, oil refinery, food, and other industries. (DOE award: $999,992; project duration: 22 months)

Novel Concepts for the Compression of Large Volumes of Carbon Dioxide

Reduced-emission power plants lose efficiency during the capture and sequestration of carbon dioxide. A large portion of this loss occurs when the CO2 is compressed for storage. Two projects will examine novel compression concepts that will be more efficient and less costly than today's approaches.

- **Ramgen Power Systems** will use supersonic shock wave technology to compress large quantities of CO2 for sequestration. Ramgen will design and fabricate a system that operates in two stages instead of the conventional six, equals or surpasses efficiency levels achieved by current compressors, and lowers costs through the simplification of system mechanics. (DOE award: $11 million; project duration: 60 months)
- **Southwest Research Institute** will improve the mechanics associated with compressing and liquefying carbon dioxide. A total-system solution will be examined, including the integration of CO2 compression technologies with other FutureGen plant subsystems. (DOE award: $175,033; project duration: 12 months)

Advanced Brayton Cycles for Highly Efficient Zero-Emission Systems

The Brayton cycle, the combustion power system most closely associated with gas turbines, can reach efficiencies of 58–60 percent in current advanced combined-cycle turbine technologies. One project will conduct a system study for advancing Brayton cycle efficiencies to 65–67 percent or higher in combined cycle applications.

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The **University of California at Irvine** will identify obstacles to integrating high-performance Brayton cycle technology modules and subsystems into safe, reliable, environmentally friendly, and economically sound power plants. Results of this project will help the Energy Department determine future research and development needs. (DOE award: $603,012; project duration: 24 months)

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