Innovative Natural-gas Technologies for Efficiency Gain in Reliable and Affordable Thermochemical Electricity-generation (INTEGRATE)

The U.S. electric system is dominated by large, central power plants and an extensive transmission and distribution system commonly referred to as the “grid.” Two-thirds of the primary energy used to generate the electricity that is fed into this grid is derived from fossil fuels (e.g. coal or natural gas) at an average net-delivered (i.e. inclusive of transmission losses) efficiency of 34%.

In pursuit of a dramatic increase in efficiency at an attractive cost, the projects of ARPA-E's INTEGRATE (Innovative Natural-gas Technologies for Efficiency Gain in Reliable and Affordable Thermochemical Electricity-generation) program will develop natural gas fueled distributed electrical generation systems that integrate a fuel cell with a gas turbine or a reciprocating internal combustion engine.

Project teams will seek to develop commercial-scale (i.e. <1MW) devices that can generate electricity at an efficiency of greater than 70% at an installed cost of less than $1.8/W. In order to do so, the teams will leverage cost and thermodynamic synergies between fuel cells and combustion engines. Specifically, the engines will generate supplemental electric power from the otherwise waste fuel and heat exhausted from the fuel cell, while helping to supply the fuel cell with the reactants that it needs.

PROJECT DESCRIPTIONS

Colorado School of Mines

High Efficiency, Low Cost & Robust Hybrid SOFC/IC Engine Power Generator – $3,006,864

The Colorado School of Mines (Mines) team will develop a hybrid power generation system using a solid oxide fuel cell stack combined with an internal combustion engine. The team’s project seeks to characterize and validate pressurized fuel cell stacks, design the hybrid system, and develop high-efficiency demonstration hardware. The system will use the hot air and exhaust gases it produces to keep components running at the proper temperatures to maximize efficiency. With this design, the team hopes to achieve robust operation with high efficiency and low capital costs.

Oak Ridge National Laboratory

Development of Next-Generation Heat Exchangers for Hybrid Power Generation – $1,000,000

The Oak Ridge National Laboratory (ORNL) team will design and develop a high efficiency, high temperature, ceramic/steel alloy heat exchanger. The novel and low cost heat exchanger will be designed by optimizing the heat transfer surface with advanced modeling and will be fabricated using advanced 3D printing technology. If successful, this innovation would enable high performance, compact heat exchangers with unconventional and complex geometries that cannot be manufactured using conventional techniques.

Stony Brook University

Hybrid Electrochemistry-Advanced Combustion for High-Efficiency Distributed Power (HE-ACED) – $2,325,000

The Stony Brook University team will develop a hybrid power system using a pressurized solid oxide fuel cell coupled to a novel, split-cylinder, internal combustion engine design. The combustion engine will use some cylinders as an air compressor, which will feed the pressurized fuel cell. The other cylinders will be fed with the "tail gas" unused by the fuel cell in the first stage, which will be ignited by high compression and burned in a lean, low temperature combustion process to produce additional power for the system.

Saint-Gobain Ceramics and Plastics, Inc.

Super High-efficiency Integrated Fuel-cell and Turbo-machinery (SHIFT) – $2,801,430

The Saint-Gobain Ceramics and Plastics team will develop a hybrid power system by pressurizing a durable all-ceramic solid oxide fuel cell stack with a specialized screw compressor/expander to boost efficiency. This sophisticated combustion engine will pressurize the fuel cell and improve its efficiency while burning the remaining "tail gas" left over from the cell as its fuel. The fuel cell stack will build on lessons learned during Saint-Gobain's work with NASA to create more robust fuel cells assemblies. The combustion engine technology will be based off work performed in an earlier ARPA-E project.

FuelCell Energy, Inc.

Adaptive SOFC for Ultra High Efficiency Power Systems – $3,099,613

The FuelCell Energy team will develop a low-cost architecture for a pressurized solid oxide fuel cell stack for integration into a variety of hybrid energy systems with unsurpassed efficiencies greater than 70%. The team will take a modular approach, building 5kW stacks that can be grouped together in a pressurized container. These modules can be added or removed as needed to suit the scale of the hybrid system, enabling a range of power applications.

Nexceris, LLC

Advanced Solid Oxide Fuel Cell Stack for Hybrid Power Systems – $2,150,356

The Nexceris team will develop a pressurized solid oxide fuel cell stack for use in hybrid power applications. The team's design improves control over the reaction of natural gas in the cell, increasing performance and durability. A novel anode current collector component provides structural support and helps define the flow of fuel gas through the stack. The 10-kW-scale cell stack building block will be housed within a hermetically sealed "hotbox" to reduce drastic changes in temperature and pressure during operation. These design features would allow for seamless integration with a turbine or combustion engine to maximize the overall efficiency of a hybrid system.

Washington State University

De-Coupled Solid Oxide Fuel Cell Gas Turbine Hybrid (dFC-GT) – $678,014

The Washington State University (WSU) team will demonstrate the technical feasibility of a hybrid power system using a pressurized fuel cell stack and gas turbine. The team's innovation centers around the integration of a membrane to concentrate oxygen from air before feeding it into the fuel cell, improving performance and boosting efficiency. The system "de-couples" the pressurized fuel cell and turbine components, allowing it increased operating flexibility.

University of Wisconsin-Madison

Integrated High Pressure SOFC and Premixed Compression Ignition Engine System – $1,012,000

The University of Wisconsin-Madison (UW-Madison) team will develop a hybrid system using a solid oxide fuel cell stack and a plug-and-play, turbocharged internal combustion that uses premixed compression ignition (PCI) to boost efficiency. Gases that leave the fuel cell, which consumes about 75% of the fuel, are pumped into the engine to be ignited by compression of the pistons. To help combust these "tail gases," the engine adds an extra burst of spark-ignited natural gas, improving engine efficiency. The UW-Madison team is targeting larger industrial applications, aiming for a 1MW system.