Advancing Fuel Cells for Clean and Efficient Power

Pacific Northwest National Laboratory is supporting the nation's need for a more environmentally sustainable, efficient and cost-competitive energy future by developing fuel cell technologies for a wide range of commercial applications.

Fuel cells offer a promising solution to the nation's energy challenges. As an energy conversion device, a fuel cell generates electricity on demand and on location—in a way that produces less pollution and harmful emissions than conventional methods of generating power. As a more energy-efficient, environmentally friendly alternative, fuel cells may be used in portable transportation as well as in residential, commercial and large-scale stationary power generation applications.

For nearly 15 years, Pacific Northwest National Laboratory has investigated materials properties, chemistry and ceramic processing for fuel cells. More recently, however, we began building on this long history and expanding our capabilities to include designing, modeling and fabricating complete fuel cell systems, most of which is focused on solid oxide fuel cells (SOFC).

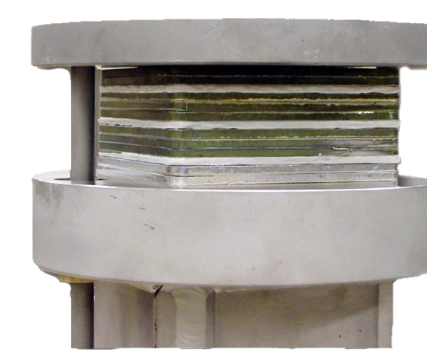
PNNL is building the science foundation necessary to accelerate high-efficiency fuel cell technologies as part of its work for the U.S. Department of Energy and industry clients.

Making progress

Researchers at PNNL are exploring the concept of building individual fuel cell modules based on a planar design that could be used individually or stacked to meet larger power requirements. We are building and testing prototype fuel cells and small stacks regularly and have seen steady progress.

Our research and development efforts address:

- Materials and manufacturing
- Modeling and simulation
- Fuel reformation
- Thermal management.



PNNL's research in the area of solid oxide fuel cells is centered on a planar design.

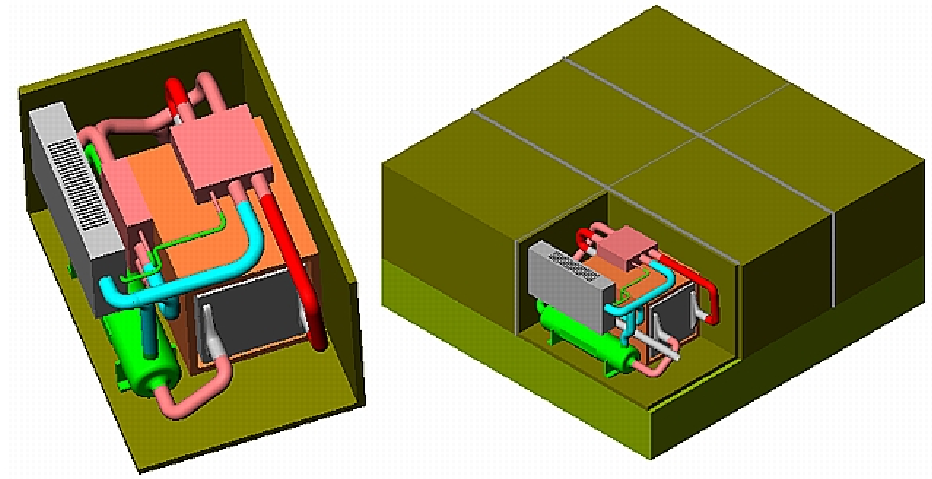
Much of PNNL's core fuel cell research is focused on advancements that could be applied to fuel cells for a variety of applications including distributed power for residential, commercial and utility power plants as well as power for military operations.

At the same time, our researchers continue investigating solid oxide fuel cells from a fundamental science perspective. DOE's Advanced Research Program is leading to new knowledge about electrochemical performance and interactions that may prove valuable in fuel cell technologies.

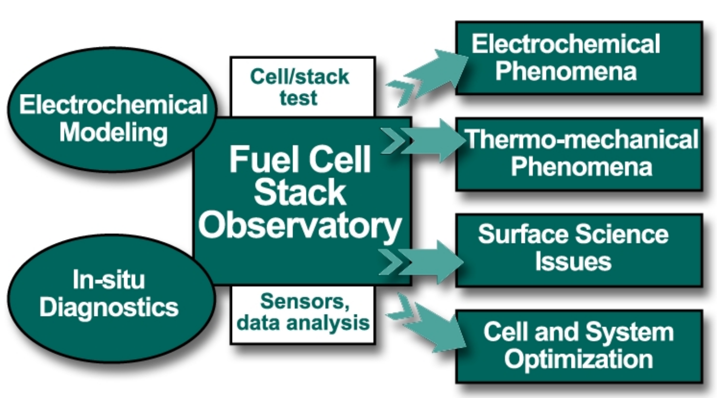
By building a better understanding of the underlying science, researchers can help determine what questions need to be answered to improve the performance and lower the cost of producing fuel cells and ensure their reliability. A planned fuel cell observatory at PNNL will provide sophisticated tools and equipment that would help researchers evaluate fundamental issues relating to the performance, reliability, degradation and interactions of solid oxide fuel cells and fuel cell stacks.

As a user facility, the fuel cell observatory also would offer a unique collaborative environment for scientists and engineers from industry, national laboratories and universities.

With the help of the fuel cell observatory, continued involvement in SECA and ongoing research and development activities, PNNL will continue contributing to solid oxide fuel cell designs and components that can be mass-produced for a variety of power-generation applications.



A proposed five-kilowatt solid oxide fuel cell module (left) will be used to meet smaller power needs or be combined with other identical modules (right) to handle larger power requirements. Pacific Northwest National Laboratory and the Solid State Energy Conversion Alliance are working to make these highly efficient fuel cells commercially available in 10 years to meet the nation's diverse power needs.



The planned fuel cell observatory is a specialized laboratory that will enhance PNNL's capability to advance solid oxide fuel cell technologies and allow researchers to investigate electrochemical, thermo-mechanical and surface science phenomena.

About PNNL

PNNL is a DOE research facility that delivers breakthrough science and technology in the areas of environment, energy, health, fundamental science and national security. It has an annual operating budget of more than $500 million and employs about 3,600 staff members.

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Fuel Cell Primer

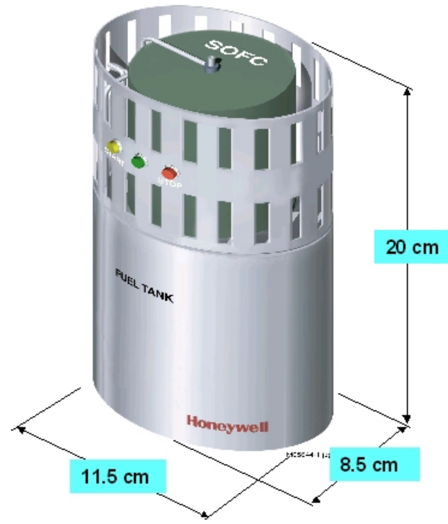
Fuel cells operate much like batteries, converting chemical energy into electrical energy. Unlike batteries, however, they never run down or require recharging. Fuel cells will continue producing electricity as long as fuel is supplied.

Because fuel cells rely on electrochemical oxidation instead of burning fuel, they significantly reduce harmful emissions such as oxides of nitrogen and sulfur. They also offer a more efficient alternative to conventional combustion-based methods for generating electricity.

Researchers around the world are developing several kinds of fuel cells because different technologies offer certain advantages in size, fuel flexibility and operating temperatures.

While some fuel cells require pure hydrogen, solid oxide fuel cells can use many different fuels directly, including natural gas. They also operate at higher temperatures than other types of fuel cells—in the range of 600 to 1,000 degrees Celsius. High operating temperatures allow for greater efficiency and speed electrochemical reactions, making it possible to avoid using expensive catalysts.

PNNL is a leader in developing solid oxide fuel cells for civilian and military applications including large centralized commercial power plants, distributed generation for residential and commercial use, and auxiliary power units for public and personal transportation.



PNNL is working on portable power generators such as this one for military applications as well as auxiliary power units for use in automobiles to meet the growing demand for additional power for electronic displays, global positioning instruments and communication devices.

In one project, PNNL and Delphi Automotive Systems are producing auxiliary power units for BMW sedans. Using a fuel cell system as a source of auxiliary power is appealing to auto manufacturers because their consumers are demanding an increasing number of advanced features that require electrical power in their cars. The fuel cell system that we are developing with Delphi Automotive Systems would replace the alternator in a conventional engine system and would provide electricity without requiring the engine to be running.

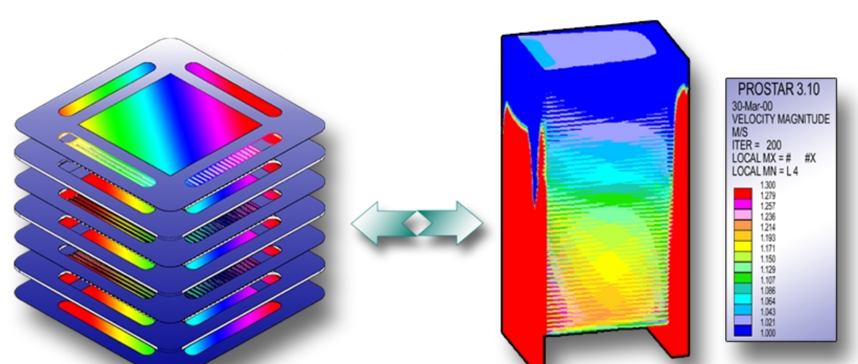
In another project, PNNL is working with Honeywell to develop components of a man-portable power source for the Defense Advanced Research Projects Agency (DARPA) within the U.S. Department of Defense. A lightweight, portable generator could meet increasing power demands for soldiers' equipment, such as heads-up displays and global-positioning systems.

Our researchers are developing advanced subsystem components, including an advanced desulfurizer system that prevents sulfur from damaging the fuel cell. PNNL is actively pursuing advanced fuel processing technology that enables fuel cells to use a wide variety of fuels such as methanol, gasoline and diesel.

Models build a better understanding

One of PNNL's strengths is our extensive modeling capability. With a unique collection of expertise and equipment, we are developing a series of computer models at the stack and system levels to better understand the normal and dynamic operation of SOFC systems.

When used together, these models could simulate the operation of the total system. The information provided by the models will assist in designing components, studying schemes for fuel and oxygen delivery, optimizing plate configurations within a multiple stack and building a better understanding of operating parameters.



PNNL's modeling and simulation capabilities are helping with optimizing individual fuel cell and fuel cell stack materials as well as answering questions about the flow and thermal distribution within the fuel cell stacks.

Broad expertise

Nearly 40 researchers at PNNL are contributing to the development of fuel cell technologies. Their areas of expertise include

- Analytical and physical chemistry
- Chemical separations and conversion
- Computational science and engineering
- Design and manufacturing engineering
- Electrochemistry
- Energy technology and management
- Materials science and technology
- Microengineering and nanoengineering

Microtechnologies offer big benefits

PNNL has developed devices for chemical and thermal systems that capitalize on the increases in heat and mass transfer rates achieved at the microscale. Many of our microtechnology projects are related to fuel processing systems. These systems are primarily developed for proton exchange membrane (PEM) fuel cells, however they also could be used with solid oxide fuel cells that are designed to operate on fuels such as gasoline or diesel.

For instance, PNNL researchers developed a microchannel fuel vaporizer—a key component for on-board conversion of gasoline to hydrogen.

We are working with the DOE's Office of Transportation Technologies on compact fuel cells for automotive use.

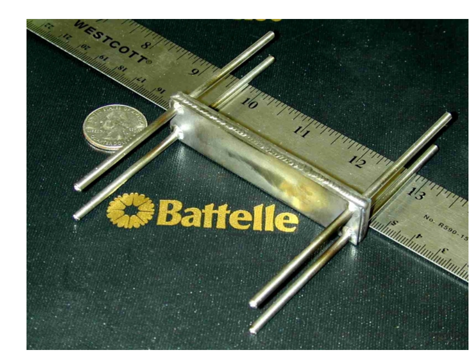
PNNL also is developing microchannel-based fuel processors to convert liquid fuels such as methanol to hydrogen for use in small, portable (1 to 100 watts) PEM fuel cell-based power systems. These systems would power portable electronic devices for the military. The work is funded by DARPA and the U.S. Army CECOM (Communications-Electronics Command).

Joining forces

In 1999, PNNL teamed with DOE's Office of Fossil Energy and its National Energy Technology Laboratory to form the Solid State Energy Conversion Alliance, or SECA. This alliance includes government agencies, commercial developers, universities and national laboratories that are striving to have solid oxide fuel cells on the market in ten years or less. SECA is leading the effort to make breakthroughs in fuel cell development that would help manufacturers commercialize solid oxide fuel cells for a variety of uses.

A PNNL representative provides oversight for the alliance as it tackles every aspect of fuel cell development from design to fabrication, materials, interconnects and modeling.

Through PNNL's involvement with SECA, we are expanding our efforts and increasing our capabilities in fuel cell research.



Our researchers have developed this microchannel-based fuel processor that converts liquid fuels such as methanol to hydrogen for use in a 20-watt PEM fuel cell power system.

The challenges ahead

Researchers are trying to increase fuel cells' efficiency and reliability while reducing their size and cost. In the years ahead, PNNL will be involved in the key research and development in areas related to advanced materials, fuel processing, system modeling and testing for improved performance, reliability and cost reductions.