Innovative Energy Solutions

Addressing the Energy Challenge

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Energy is critical to our quality of life. It helps provide for the continued prosperity of the United States and plays an important role in national and global security.

As the economy grows, our nation's needs for energy will grow. According to projections by Pacific Northwest National Laboratory, demand for electricity in the United States will require nearly $500 billion in new generation resources and energy infrastructure by 2020. Globally, substantial investments in energy are crucial to improving the standard of living in developing countries.

At the same time, our country is growing more conscious of the environmental consequences of energy use—particularly global warming. The energy challenge requires more than simply providing electricity for growth and prosperity. It requires addressing global climate change by stabilizing and then reducing the concentration of carbon dioxide in the atmosphere.

The U.S. Department of Energy is committed to advancing the energy security of our country. At PNNL, scientists are responding to the DOE's mission by conducting innovative research and development to create new technologies for providing clean, secure and affordable energy.

Re-thinking the current energy picture

No magic bullet

There is no single solution to the energy challenge. Fossil, nuclear and renewable energy sources, such as biomass, solar and wind, all must contribute—and so must increased efficiency.

PNNL looks at integrated energy systems that include energy generation, transmission, distribution and end use in industry, in the home and for transportation. Our energy research considers different aspects of the energy system, including technologies to use existing resources more efficiently, new technologies such as fuel cells and other hydrogen-based systems, options for carbon management and a vision for the energy grid of the future.

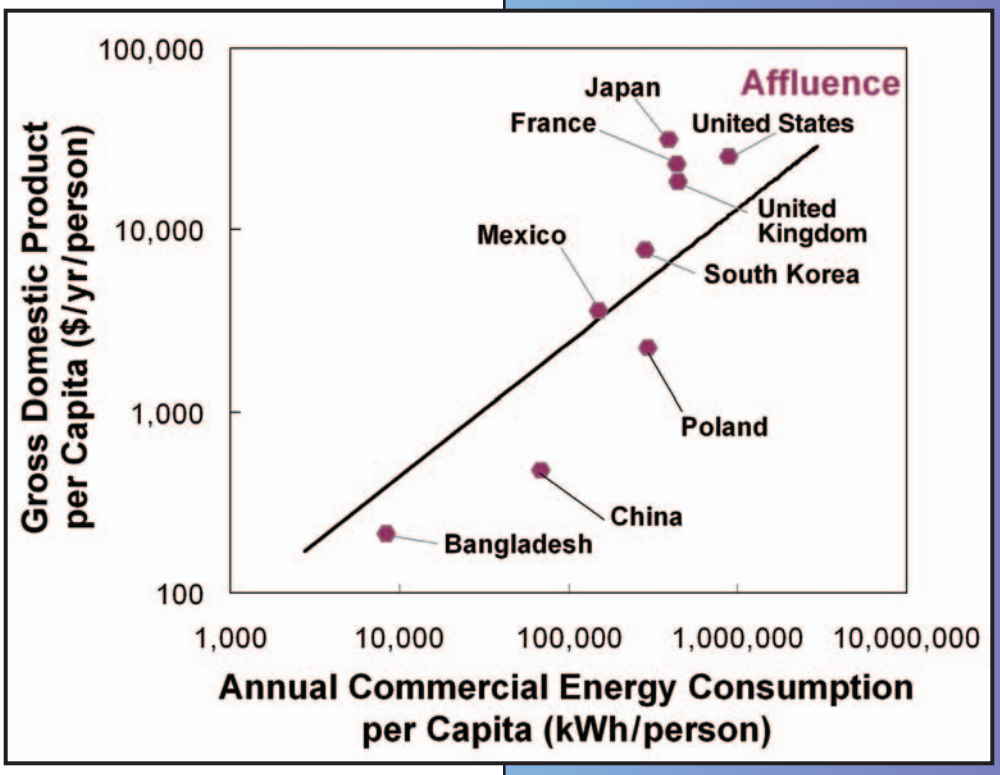
Protecting our atmosphere

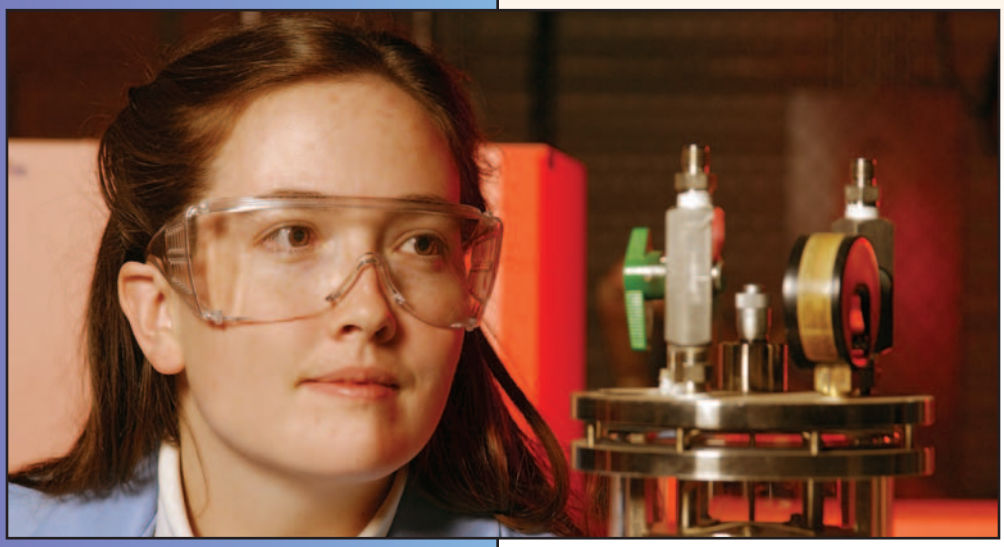
Researchers at PNNL are developing the mechanisms to capture and then sequester underground the carbon dioxide that comes from burning fossil fuels in a process called geologic carbon sequestration.

In one sequestration project, we are working with Alaskan collaborators to assess the possibility of using carbon dioxide to harvest methane gas trapped in ice-like solids called hydrates. If this "swap" proves effective, carbon dioxide would be

Affordable energy drives prosperity

A nation's gross domestic product per capita is directly proportional to its annual commercial energy consumption per capita. For example, less affluent countries such as Bangladesh have low commercial energy consumption and low GDP. More affluent countries, such as the United States and Japan, are among the highest in energy consumption per capita and GDP. (World Resources Institute Database 1996-1997)





forced beneath the earth, freeing a large domestic fuel source in exchange.

PNNL researchers also also playing a lead role on a combined U.S. Department of Energy and industry effort to build a 275-megawatt power plant that will gasify coal to produce electricity and hydrogen. In that gasification process, carbon dioxide will be captured and sequestered.

The program, called FutureGen, aims to design and build energy plants that maximize the efficiency of fossil fuel energy generation while minimizing the environmental effects. PNNL is partnering with the National Energy Technology Laboratory to develop technologies in support of the FutureGen vision.

The High Temperature Electrochemistry Center (HiTEC) builds on this collaboration. As part of the HiTEC team, PNNL researchers are applying their expertise in materials science, solid state electrochemistry and surface chemistry to develop new materials and new ways to form and manufacture them to meet the cost and performance goals of the FutureGen plant. The HiTEC project includes collaboration with universities through the creation of satellite research centers.

Creating more value from biomass

By developing new technologies that transform low value biomass residues into higher-value products, scientists are helping make the bioprocessing industry more profitable so that biofuels can be produced more economically.

PNNL is a leader in developing and applying novel processes to convert biomass into industrial and consumer products. These processes convert the chemical building

Fuel consumption

Two-thirds of the 20 million barrels of oil our nation uses each day is used for transportation. The United States imports 55 percent of its oil, and this figure is expected to grow to 68 percent by 2025 under the status quo.

blocks of agricultural materials (biomass) into everyday products—plastics, adhesives, fibers, liquid fuels and power—that are now produced from imported petroleum.

We currently are working with private industry and government to translate these conversion process discoveries into deployable technologies that will reduce our reliance on imported oil. PNNL's capabilities in catalysis and in fungal biotechnology are the foundation of this work.

PNNL is using specialized combinatorial catalysis instrumentation to improve chemical catalysis in biomass systems. We are working on catalyst systems specifically developed for aqueous systems to economically produce higher value chemicals from the sugars and oils in biomass residues.

PNNL's research also examines the use of novel filamentous fungi to assist in the production of bio-based products. We are applying methods such as proteomics and bio-informatics to understand the genetic controls associated with regulating behavior such as morphology, nutrient uptake, protein expression and enzyme production. These tools will lead to new products and fuels from bio-based processes using fungal species.

To further expand the bioproducts effort, PNNL and Washington State University are constructing a bioproducts research facility at WSU Tri-Cities in Washington

state. The Bioproducts, Sciences, and Engineering Laboratory will provide classrooms, teaching laboratories and engineering development laboratories, benefiting both students and researchers.

PNNL plays a key role in public-private partnerships aimed at reducing harmful emissions and raising fuel efficiencies for cars and trucks. This work includes developing catalyst materials and

Emissions—from source to cell

As our country makes the gradual transition to cleaner forms of energy, such as hydrogen, scientists at PNNL are developing technologies to address the environmental effects of fossil fuels, such as coal, natural gas, petroleum and oil, while we continue to use them.

Emissions research at the Laboratory considers the problem from "source to cell." Not only are we developing technologies to reduce emissions such as oxides of nitrogen (NO_X) and particulate matter from vehicles, we also are building a scientific understanding of how emissions react and spread in the atmosphere and how they affect human health.

nonthermal plasma to meet the next generation of emissions requirements.

Scientists and engineers at PNNL have set up a new automobile emissions lab to help deal with the technical challenges involved in developing a process for diesel engines that cleans up NO_X in

Reducing automotive pollution

The automobile industry is under a great deal of pressure to produce and market low emission vehicles. According to a new federal law to be phased in over the next five years, diesel engines in cars must be 90 percent cleaner than they are today. Diesel-powered 18-wheelers will be required to meet new emission standards by the end of the next decade.

engine exhaust much like the catalytic converter process in gasoline-fueled engines.

Dealing with particulate matter is a second challenge for scientists

working on aftertreatment devices or diesel engines. Diesel engine combustion is more stratified than gasoline engine combustion. This leads to improved efficiency, but creates more particulates. Scientists at PNNL are developing innovative technologies that could be used in conjunction with the NO_x treatment system on a diesel engine to reduce particulate emissions.

The emissions lab is just one element in PNNL's emissions program. Combined efforts by fundamental scientists who employ sophisticated surface analytics and computer modeling capabilities are being used to develop materials, configurations and other information for testing in the emissions lab.

Nuclear Energy—clean and inexpensive

Nuclear energy generates 20 percent of the electricity in the United States today. Because it doesn't emit any greenhouse gases, it is likely that nuclear energy will continue to play a significant role in future energy generation. PNNL researchers are using their expertise in materials science to help the Nuclear Regulatory Commission guarantee that materials in existing nuclear reactors will withstand harsh, radioactive environments so that reactor components provide

Efficiency: Diesel scores high

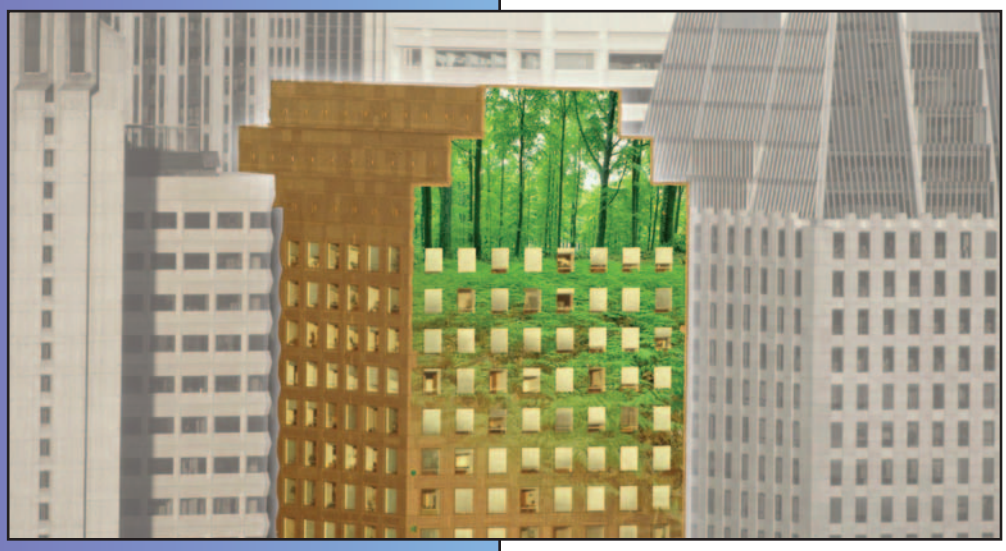
If all the cars and trucks in the nation today ran on diesel, fuel efficiency would increase so much that the United States would no longer need to import oil from the Middle East.

safe, reliable ongoing operations. We also have the capacity to assist the NRC if it begins to license new plants in the future as well as the expertise to assist the DOE in developing the advanced fuel cycles necessary to support such new plants.

Developing more efficient industrial technologies

PNNL is committed to improving the energy efficiency of U.S. industry by delivering high quality research and development on advanced process systems, advanced industrial materials, and chemical and enabling technlogies. Our support of DOE's industrial technologies program builds collaborative teams with industrial partners throughout the United States to leverage their expertise and drive commercialization of new technology.

For example, we are teaming with five organizations to develop low-cost thermoelectric systems with 20- to 40-percent efficiency for recovering waste heat in process industries and vehicle exhaust systems. This research will include thin film design, multilayer chemistry and tailored interfaces, and thermal and electrical modeling.



Creating energy-smart buildings

PNNL's Buildings Program develops energy efficient technologies and supports energy code and standard advancement to reduce building energy intensity, leading to healthy, productive and secure places to live and work. We're a leader in building system condition monitoring, diagnostics, prognostics and control, including wireless technologies

enabling reduced energy consumption, lower operating costs and enhanced peak energy management. Emerging research and development areas include solid state lighting using organic light-emitting diodes and microtechnology-based heat pumps. We enhance energy efficient technology use by supporting DOE's advancement of building energy codes and standards, developing innovative processes for stimulating energy efficient product development and partnering with federal, state and other public agencies.

New technologies for cleaner, more efficient energy

Powering the future with hydrogen

As our nation's energy needs grow, so does our need to find cleaner, more efficient ways of producing energy.

Hydrogen is a potentially limitless energy source that doesn't emit greenhouse gases or carbon dioxide, so it can play a major role in meeting our country's need for clean energy. Increasing our use of hydrogen as an energy source also could mean decreasing our reliance on foreign oil.

One of the main barriers to a hydrogen economy is hydrogen storage. Hydrogen will need to be used and stored safely and economically. At PNNL, we're using our capabilities in three key areas—chemistry, catalysis and materials—to explore innovative chemical storage mechanisms to ensure hydrogen storage systems can be reused and recharged safely and economically in a practical time frame.

For example, PNNL's expertise in theoretical and computational chemistry and catalysis will play an important role in DOE's Center for Chemical Hydrogen Storage. PNNL is co-leading the center, where researchers will design a practical, cost-effective and energy-efficient hydrogen storage system that also will be able to refuel or regenerate hydrogen.

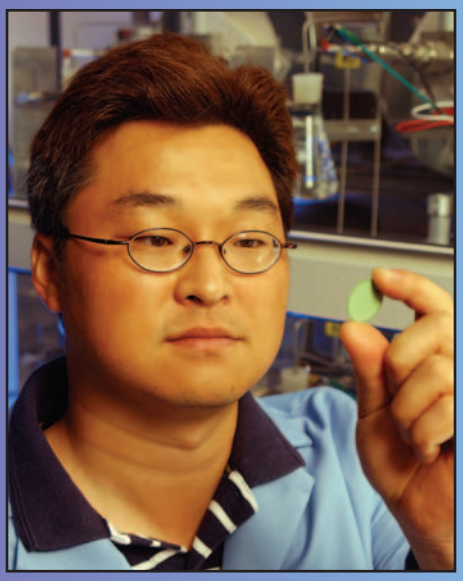
As the lead DOE laboratory for hydrogen safety, PNNL scientists are developing codes and standards for the safe use of hydrogen systems at the pump and in operation.

Advancing fuel cell technology

PNNL is a leader in developing solid oxide fuel cells (SOFCs), which can be used for stationary power, transportation and military needs. SOFCs are the fuel cell of choice for converting fuel into electricity to provide a vehicle's auxiliary electric needs, taking the load off the engine to increase efficiency and reduce emissions. SOFCs also can be fuel flexible. In addition to being able to run on pure hydrogen, SOFCS can—with the help of fuel reformation—effectively use conventional fuels, such as gasoline, diesel and natural gas.

As part of its fuel cell work, PNNL and the National Energy Technology Laboratory are co-leading the Solid State Energy Conversion Alliance (SECA), a DOE program involving several industry teams devoted to promoting and accelerating the development and commercialization of low-cost, environmentally friendly SOFCs for a variety of applications.

From understanding how materials behave in certain conditions to modeling the performance of entire fuel cell systems, our researchers are advancing fuel cell technology.



Propelling the energy grid into the 21st century

Researchers at PNNL are working on an exciting new way to modernize the energy grid and make distributed energy a reality. This concept, called GridWise™, is a market-driven system that allows

a back-and-forth flow of information from generation to end use, where both individual consumers and industry can customize energy purchases based on economics, types of power and time of use.

Creating an information-rich system based on the two-way, real-time flow of information creates a dynamic, interactive system that will offset traditional infrastructure investments while increasing system robustness, flexibility and security.

PNNL's GridFriendly controller is part of this vision. The GridFriendly controller can turn off air conditioners or water heaters momentarily when there is a disturbance on the grid. The automatic response would go unnoticed by consumers, yet would prevent a major outage by adjusting demand to allow the system time to reconfigure.

The system's interactivity, combined with technology such as the GridFriendly controller, would monitor the grid in times of stress so that if there is a disruption and a plant goes down, interruptible appliances such as hot-water heaters could immediately detect a problem and shut themselves down briefly, reducing the load and giving the system time to heal.

Because it is based on a two-way flow of information, the GridWise concept is flexible enough to include distributed energy generation sources, such as windmills, solar power panels and small hydro plants, in addition to large central station generation. All of these small power sources would be "plug and play" resources.

Fuel cells support distributed energy because they can be located at the point of use and energy production can be increased incrementally by adding more fuel cells as energy needs increase, reducing the need to build more power plants.

PNNL energy experts also are leading efforts to create a synchronized data management and communication infrastructure over the Eastern power grid. The Eastern Interconnection Phasor Project (EIPP) provides the first real-time, system-wide data to utilities and transmission operators within the Eastern power grid.

Assessing today's energy system

The August 2003 blackout on the East Coast highlighted the vulnerability of the grid to technical disruption, natural disaster or terrorism.

About Pacific Northwest National Laboratory

The U.S. Department of Energy's Pacific Northwest National Laboratory, operated by Battelle, advances the fundamental understanding of complex chemical, physical and biological systems and provides science-based solutions to some of the nation's most pressing challenges in national security, energy and the environment. We accomplish this mission through the outstanding research and development activities of our staff, excellence in operations and high-value partnerships.

PNNL has approximately 3,800 researchers and staff located at the main campus in Richland, Washington, the Marine Research Operations facility in Sequim, Washington, and at offices in Seattle, Washington, Portland, Oregon, and Washington D.C.

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