3—Energy

3.0 PNNL's Role in DOE's Energy Research Mission

PNNL will expand scientific knowledge and create breakthrough technologies for the energy system of the future, enabling secure, clean, and affordable energy in a carbon-constrained world.

Our R&D in support of DOE's energy mission is aligned with two parallel paths—one that focuses on using existing resources in the most efficient and environmentally acceptable manner possible, and one that focuses on bridging the gap between today's energy systems and tomorrow's hydrogen economy. Our unique combination of multidisciplinary capabilities and a vision of the energy system of the future positions us for leadership in developing a comprehensive, intelligent national grid that includes energy generation, transmission, distribution, and end use in industry, in the home, and transportation. By combining information, simulation, and visualization technologies with new energy technologies, we will increase the nation's energy security and reliability, dramatically reducing the need for expensive new energy infrastructure.

Energy

Our expertise extends from basic science to technology development and deployment. We will apply these capabilities and collaborate with industry, universities, and other national laboratories to maximize the benefit to DOE's energy mission, the nation, and the world.

Developing Technologies for Clean and Efficient Power Generation

We develop technologies for meeting growing energy demands in ways that are economically viable, minimize the release of greenhouse gases, and reduce our dependence on imported oil. While we are exploring a transition to a hydrogen economy, our near-term efforts will focus on maximizing energy efficiency, increasing the use of renewable energy, and using nonrenewable resources in environmentally acceptable, economic ways. For example, our fuel cell technologies, our scientific understanding of thermoelectric materials, and our carbon sequestration analyses and pilot projects are relevant to DOE's FutureGen program, aimed at constructing the next-generation fossil fuel energy plant (Module 3.3). Through our participation and leadership in the Solid State Energy Conversion Alliance (SECA, Module 3.3.1), we will strive to reduce the cost of solid oxide fuel cells by 50 percent. Nuclear power currently provides about 20 percent of the nation's electrical generating capacity; our material scientists are recognized world leaders in evaluating the ability of existing nuclear power plants to extend their operating licenses to produce electricity without generating greenhouse gases.

Expanding Bio-Based Products

In support of the nation's need to reduce its dependence on imported oil, our researchers are exploring technologies to make bio-based products and fuels more prevalent and economically viable (Module 3.1.3). Building upon our expertise in catalysis, we conduct research to transform agricultural byproducts into high-value chemicals and products, which supports the Office of Energy Efficiency and Renewable Energy's (EERE) goal to create a $1 billion annual bioproducts business in the United States.

Developing Hydrogen Systems

To encourage a successful transition to a hydrogen economy, we bring together policy and analysis expertise as well as scientific capabilities that are directly applicable to the challenges associated with hydrogen production, storage, distribution, and safety (Module 3.1.1). In 2003, we were assigned leadership of DOE's hydrogen safety program. During the next several years, we will conduct integrated analysis and evaluation of hydrogen systems as part of the President's Hydrogen Initiative.

Leading the Vision of the Grid of the Future

Our vision of the grid of the future, known as GridWise™, will harness the power of information technology and new energy technologies to transform the energy system into one that is intelligent, robust, reliable, and secure. This vision addresses national needs by modernizing the energy system into the information age, making it possible to 1) reduce the need for expensive infrastructure, 2) incorporate and value the contributions of distributed energy solutions, 3) increase the security of critical infrastructure, and 4) visualize the system in ways that makes it understandable, manageable, and transparent to system operators and regulators. We are particularly well-suited to integrate this vision because of our scientific capabilities and experience with practical applications related to many aspects of the energy system. These capabilities include modeling and computation, grid reliability, materials science, development of fuel cells and other innovative energy technologies, and economics and policy analysis. This comprehensive, intelligent national grid has the potential to save the nation nearly $80 billion of the roughly $450 billion of projected investment needed in energy infrastructure to accommodate growth over the next 20 years.

Advancing Transportation Technologies

Based upon our materials, catalysis, and surface interaction science, we are developing advanced technologies for transportation, such as lightweight materials, solid oxide fuel cells, and emission aftertreatment technologies for passenger vehicles and trucks (Module 3.1.2). These technologies help increase fuel efficiency and reduce emissions in the transportation sector, which is responsible for a third of the nation's carbon dioxide emissions and today relies almost entirely upon fossil fuels.

Primary Energy Customers

Our energy-related R&D supports the needs of several offices within DOE, including EERE (Modules 3.1 – 3.1.4); the Office of Fossil Energy (FE, Modules 3.3 and 3.3.1); and the Office of Nuclear Energy, Science, and Technology (NE, Module 3.5); as well as the newly formed Office of Electric Transmission and Distribution (OETD, Module 3.2) and DOE's Climate Change Technology Initiative (CCTI, Module 3.4).

The programs and initiatives described throughout Chapter 3 of this Institutional Plan discuss how PNNL supports DOE in providing secure, clean, and affordable energy, and are closely aligned with the Laboratory Agenda items, shown here.

3.0.1 Energy Mission Funding and Staff

PNNL estimates 35 percent growth in its energy mission activities between FY 2002 and FY 2008.

Key Growth Areas

The majority of our energy business and new opportunities will come from EERE. While a smaller component of our overall energy business, support for FE will nearly double by FY 2008. Funding from NE will likely see the most modest growth.

Energy Efficiency and Renewable Energy

The largest areas of growth for PNNL within EERE relate to biomass research, hydrogen, and fuel cells. This business may expand by much as to $15 million during the next five years. These areas of expected growth are aligned with national initiatives, as well as Laboratory initiatives supported by internal investments. Projects that traditionally fall within the Distributed Energy and Electricity Reliability program will also see significant growth; however, because of reorganization within DOE, most of this research and development will eventually be moved to OETD (Module 3.2). This new office will include research related to the grid of the future and the reliability of the electricity infrastructure.

Energy

Within EERE, we expect to see decreased funding over time within the Federal Energy Management Program and Weatherization. Our relative portion of these overall budgets are expected to remain about the same during the FY 2004–2008 planning period, but trends indicate a shift in the federal government's priorities and dramatic decreases in DOE's overall budgets in these areas. For example, the Federal Energy Management Program budgets at the national level are being reduced by 15 percent in FY 2004. Even so, we will work to preserve our core business in these areas because these resources and our related capabilities are critical to our ability to build business in other areas of growth.

Fossil Energy

Three key areas of funding for our energy research from FE are expected to see growth during the FY 2004–2008 planning period: the SECA, the High Temperature Electrochemistry Center, and carbon management and sequestration. These three areas all support FE's FutureGen Initiative (Module 3.3), which aims to build the energy-efficient, emission-free fossil energy plants of the future.

Our expanding relationships with collaborators such as NASA and Boeing in the area of solid oxide fuel cells may bring new revenues to the Laboratory and shore up impactful funding sources. However, achieving the targets for growth in funding directly from FE projected on the chart shown here will require new business areas, such as carbon management and carbon sequestration demonstration projects or emission research. During the next five-year planning period, a portion of the work traditionally designated as part of FE will be aligned with the newly created CCTI within DOE (Module 3.4).

Nuclear Energy, Science, and Technology

While we project modest growth in funding from NE, achieving these targets will require that we move into program areas such as space power, next-generation reactors, or reprocessing—new programs that are not currently receiving significant funding. We plan to build on our experience and strengths related to understanding the effects of radiation on materials.

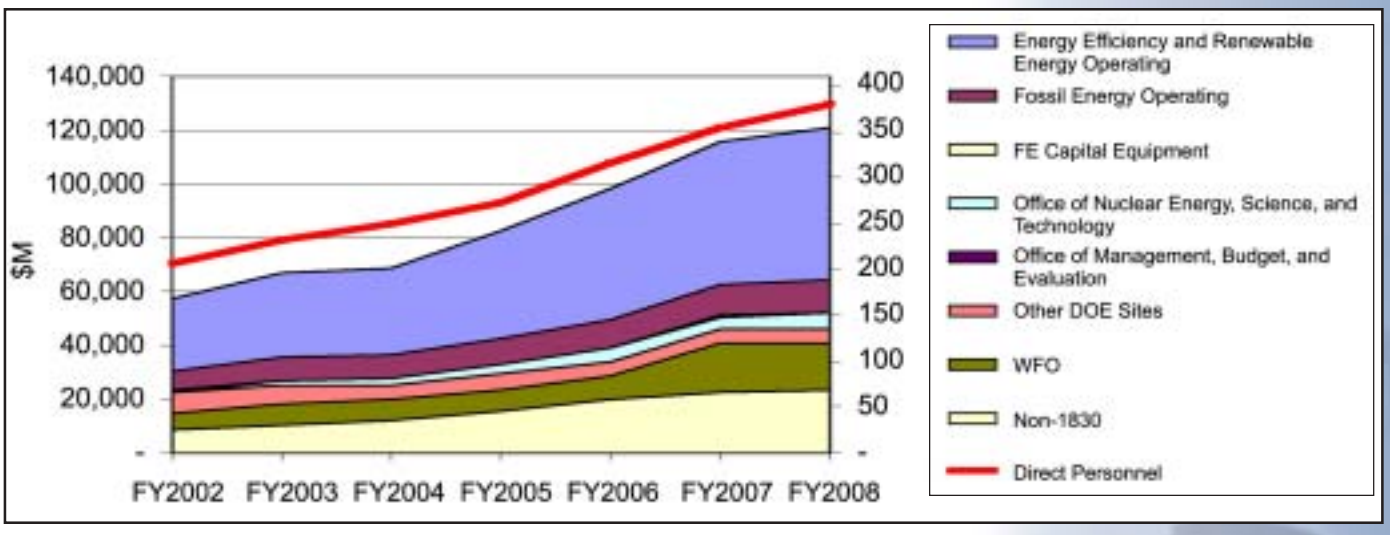
Work for Others

Our energy research for other government agencies and industries (Module 3.6) includes work for:

- Bonneville Power Administration (BPA)
- U.S. Nuclear Regulatory Commission (NRC), where we expect modest growth
- energy companies, where we expect to see increases over the planning period
- European Bank for Reconstruction and Development.

Resources aligned with the private energy industry focus primarily on work related to the automotive industry, industrial partnerships related to carbon sequestration, opportunities for new hydrogen demonstration projects, and collaborations with utilities and other private companies in pursuit of an energy system transformation or part of the GridWise activities (Module 3.2.1).

One reason for a slight decrease in this sector is that over time, we expect the work related to the former Soviet Union and nuclear reactor safety to decline as the first phase of planning and consulting related to projects under the European Bank for Reconstruction and Development (including the new safe confinement of the Chornobyl reactor) is completed. In part, these decreases are expected because more European support is available to implement the plans and complete longer-term projects.



All PNNL energy mission areas show steady growth through 2007.

3.1 Maximizing Energy Efficiency and the Use of Renewable Energy

PNNL will strengthen America's energy security, environmental quality, and economic vitality by applying its capabilities to increase the use of renewable energy and maximize energy efficiency.

With a long history of funding from EERE and strong linkages to private industry, we are enhancing energy efficiency and productivity, bringing clean, reliable, and affordable energy technologies to the marketplace, and reducing America's dependence on imported oil. Our scientific and technological contributions in this area are aligned with DOE's vision for the energy future that includes:

- increasing efficiency in cars and trucks and powering them with clean domestic fuels
- reducing energy costs and increasing efficiency for homes and industry
- revitalizing the electricity infrastructure, making it more robust and reliable
- increasing the use of renewable resources and the quantity of power generated by homes, businesses, and communities and sold back to local generators
- creating industrial energy parks that use and produce energy
- improving the economy for rural America through biomass feedstocks for biorefineries that produce power, fuels, chemicals, and other valuable products
- developing leadership in conserving energy and using renewable energy resources within the federal government.

Energy

Strategic Integration

Our expertise in surface characterization and catalysis, systems integration and analysis, modeling and simulation, and diagnostics and prognostics provides a strong foundation that directly supports DOE mission needs related to renewable energy and energy efficiency. We also are building our scientific capabilities in electrical engineering and economics to help bolster the transformation of the electrical infrastructure. We are pursuing an opportunity to bring together several disparate pieces and legacy programs, including several funded by EERE and some now managed by OETD (see Module 3.2), under a single strategy for the energy system of the future. This strategy integrates energy generation, demand management and distribution, and environmental concerns to meet the electricity demands of today, and the use of hydrogen for distributed generation and transportation in the future.

Partnerships, Collaborations, and Leveraging Resources

Regional partnerships play an important role in our support to EERE's mission. For example, we were a founding member of the Northwest Energy Technology Collaborative, formed in 2002 to accelerate the growth of the energy technology industry in the Pacific Northwest. This partnership includes the Washington Technology Center, Avista Corporation, BPA, Spokane Intercollegiate Research and Technology Institute, the Washington State Office of Trade and Economic Development, and the Inland Northwest Technology Education Center.

We will continue to invest internal resources to improve our ability to respond to DOE's needs and will continue to rely on our strong linkages with industry to leverage funding from EERE, as well as funding from FE, the Office of Science (SC), and the Office of Basic Energy Sciences (BES) to further advance energy technologies in solid oxide fuel cell research, vehicle technologies, and microtechnologies. For example, we are leveraging FE's SECA (Module 3.3.1) and our leadership in this alliance to pursue the development of solid oxide fuel cells for transportation and auxiliary power.

We also will use SC facilities at the Laboratory for EERE missions such as furthering our understanding of emission chemistry in the atmosphere and its impacts on human health.

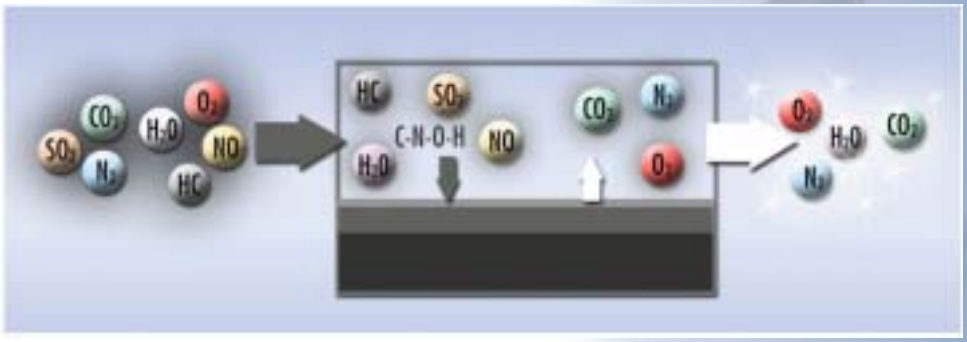
PNNL is committed to improving the energy efficiency of U.S. industry by delivering high-quality R&D on advanced process systems, advanced industrial materials, and chemical and enabling technologies. Our program aims to build collaborative teams with industrial partners throughout the United States to leverage their expertise and drive commercialization of our technology. For example, our largest project in FY 2004 teams with five organizations, and focuses on developing 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.

Wind and Hydropower Technologies

Our scientists also conduct R&D aimed at building more environmentally friendly technologies to maintain the nation's existing hydropower capacity in support of the Office of Wind and Hydropower Technologies. For example, we help define biological specifications for safe operation of hydropower turbines and test turbine design and modifications. In the next five years, we will coordinate our research portfolio in this area to include the BPA, the Western Area Power Administration, private utilities, and the Army Corps of Engineers.

Planning and Analysis

PNNL also provides analysis and process development to EERE. Our activities is this area include evaluating energy impacts of past programs, assessing potential impacts of new programs, and providing integral support to the multiyear planning process.



PNNL applies its expertise in surface chemistry and catalysis to develop technologies that reduce harmful emissions from diesel engine exhaust, converting oxides of nitrogen and particulate matter into components of clean air. These same surface chemistry capabilities will be valuable in addressing technical challenges related to bio-based products and fuels, vehicle technologies, carbon capture and sequestration, and advanced energy systems.

3.1.1 Hydrogen S&T

PNNL will lead the hydrogen safety program and make advances in S&T for a hydrogen economy of the future, helping the United States lead the world in developing clean, hydrogen-powered automobiles, and in the development of hydrogen production, storage, and delivery technologies.

The President announced two initiatives in 2003 related to hydrogen: the Hydrogen Fuel Initiative and FutureGen (Module 3.3). Paving the way for hydrogen's rapid growth as an energy carrier over the next several decades will require achieving the goals of hydrogen technology and favorable regulations and policies.

Our internal investments and programmatic efforts in hydrogen R&D have positioned us to become a key provider of cutting-edge S&T relevant to the national hydrogen program, including:

- hydrogen storage materials
- hydrogen production technologies
- science and engineering in support of hydrogen safety
- reforming technologies and auxiliary power units and sensors.

We are also engaged in establishing regional collaborations that deal with deployment and testing of the hydrogen system of the future.

Energy

The long-term National Hydrogen Vision is "*a prosperous future for the nation where hydrogen energy and fuel cell power are clean, abundant, reliable, and affordable, and are an integral part in all sectors of the economy and all regions of the country*."

Production

We are developing technological solutions for the production of hydrogen from diverse renewable sources. The following attractive and technically viable approaches build on current laboratory capabilities.

- **High-temperature steam electrolysis**, which has the potential to reduce substantially the electrical requirements to convert water into hydrogen and oxygen. We will build on our capabilities in planar solid oxide fuel cells and the High-Temperature Electrochemistry Center in pursuit of this option (Modules 3.3.1 and 3.3).
- **Gasification of biomass feedstocks,** which uses high-activity catalysts in water solvents at moderate temperatures and pressures. We will build on our expertise in catalysis, reactors, and feedstock conversions to extend the scope of bio-based products research (Module 3.1.3.1) from high-value chemicals to hydrogen production.
- **Photocatalyzed water splitting using single-cell algae**, in which hydrogen and oxygen production are physically separated, avoiding one of the most challenging issues in bio-photocatalysis. We will build on our expertise in genetic modification to increase productivity of the algae.

Storage

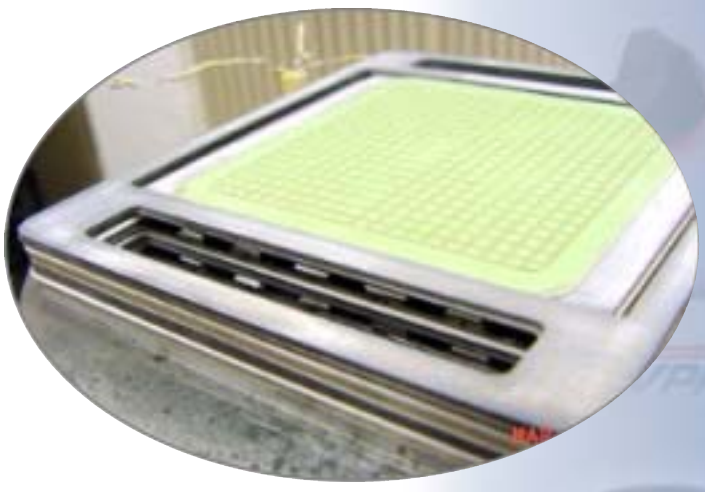
The hydrogen storage challenge must be addressed for a hydrogen economy to be realized. Using today's technology, vehicles could carry only enough hydrogen to travel about 150 miles—the goal is to be able to travel 300 miles. To accomplish this goal, new materials are needed that provide volumetric and storage capacity, or further understanding of existing materials to increase their storage capacity. We are teaming with Los Alamos National Laboratory on a proposal to establish a center-of-excellence for research on chemical hydride storage materials. Such a center will take advantage of our experimental, characterization, and computational chemistry capabilities (Module 2.4.1) and the capabilities being developed as part of the Nanoscience and Technology Initiative (Module 2.3.1). We also have begun capability-development projects to further develop our understanding of the fundamental mechanisms of hydrogen storage in metal hydrides. SC and EERE are teaming on the development of advances that require basic understanding of materials.

Safety

Hydrogen is a new fuel for widespread use; therefore, there is a need to establish codes and standards and to increase awareness and the public perception related to its safety. We have been designated by DOE's Fuel Cells, Hydrogen, and Infrastructure Program as the national lead for the hydrogen safety program. An integrated approach to safety will establish crosscutting activities that identify all aspects of risk and effectively and economically address them. As part of leading the integrated safety program, we will test hydrogen systems, develop sensors to detect hydrogen leaks, and establish best practices for hydrogen safety. We also will continue exploring the possibility of using the Hazardous Materials Management and Emergency Response (HAMMER) training facility in Richland, Washington, as the main facility in the nation for hydrogen safety training of fire marshals and code officials. In addition to supporting the DOE's hydrogen programs, integrated hydrogen safety will also support the goals of DOE's FutureGen program.

Regional Collaborations

We are developing industry relationships as well as engaging regional and national interests in the creation of a Northwest Hydrogen Initiative. While this effort is just beginning, it will focus on developing a hydrogen infrastructure demonstration project, to characterize and communicate the societal benefits of a hydrogen economy, and to accelerate the development of national safety standards.



Planar solid oxide fuel cell technology provides a platform for developing high temperature steam electrolyzers for producing hydrogen.

Energy

3.1.2 Vehicle Technologies: Advanced Lightweight Materials and Emission Aftertreatment

By building understanding of lightweight materials, including composites that could reduce vehicle weight by as much as 60 percent, and by developing exhaust aftertreatment technologies for diesel engines that could double the fuel efficiency in standard light-duty vehicles, PNNL is contributing to dramatic increases in vehicle fuel efficiency.

Our R&D efforts directly support EERE's FreedomCAR and Vehicle Technologies Program. This program works in partnership with the domestic transportation industry, the energy supply industry, and R&D organizations to develop and promote user acceptance of advanced transportation vehicles and alternative fuel technologies. The primary goal for the FreedomCAR and Vehicle Technologies Program is to increase fuel efficiency to stop or reverse the annual upward trend in the quantity of petroleum fuels used by highway transportation vehicles. Secondary goals include reducing specific pollutant emissions and greenhouse gases and developing a strong transportation technology base that enables industry to ensure strong competition in the domestic and world markets.

Lightweight Materials

We are helping DOE achieve its goals related to transportation technology through our work in developing a new class of low-cost materials (e.g., thermoplastic composites, magnesium and titanium alloys), forming and joining technologies, and advanced computational design and manufacturing simulation tools to address key national technical needs for reducing vehicle weight and enabling the development of hydrogen powered fuel cell vehicles. We are collaborating with Oak Ridge National Laboratory on several of these efforts.

Through our CS&EI (Module 2.4.1) we have developed core capabilities in computational modeling of composite material systems that can use basic constitutive properties and processing knowledge to predict mechanical and thermal properties and, as such, enable the discovery of a new class of high-strength, low-weight materials.

Emissions Research

We are developing exhaust aftertreatment systems to control harmful pollutants in diesel exhaust emissions, providing a key enabling technology for widespread use of diesel engines in the United States. Diesel engines provide the best near-term approach to reduce U.S. petroleum consumption and reduce carbon emissions to the atmosphere. We are also applying capabilities in surface chemistry, catalyst mechanisms, models, material synthesis, and aerosols to build an understanding of

catalytic processes and advance the development of practical aftertreatment devices that can be commercialized for diesel engines. This area of research will also build on SC's focus on catalysis and plans for a catalyst laboratory.

Our vision for the future is that we will have a laboratory for engine exhaust and emissions research (Module 3.7) that will provide capabilities for understanding phenomena in aftertreatment devices, experimentation and modeling focused on mesoscale aspects of emissions reduction technology, and rapid materials innovation. This facility would allow for an integrated approach that includes mechanism investigation, modeling, and materials/system optimization, leading to testing and validation.

The critical component of any engine emission device is the catalyst, so increasing our fundamental understanding of catalysts is imperative for advancing these technologies.

PNNL is developing exhaust aftertreatment systems that could enable widespread use of diesel engines. At this time, diesel particulate filters such as these are highly effective for pollution abatement, but are not sufficiently developed for widespread deployment.

Energy

3.1.3 Catalysis for Bio-Based Products and Fuels

PNNL is developing methods for cost-effective conversion of complex biomass and synthesis gas into fuels for use in transportation and generation of electrical power.

Our chemical and biological capabilities enable us to develop breakthrough processes for bio-based products and fuels. These efforts support two key priorities of EERE—reducing the nation's requirements for imported petroleum and advancing the economic viability of a U.S. bioproducts industry. In addition, these capabilities are applied to produce higher-value chemical intermediates from synthesis gases, sugars, and oils. Our technologies are critical technical and financial components of DOE's vision for an "integrated biorefinery of the future," that complements ethanol production and creates a financially robust energy and bioproducts industry based upon renewable resources.

Innovative Catalysis Research for Products from DOE's Sugars Platform

Building upon fundamental knowledge of catalytic processes and catalyst formulation, including advanced biocatalysis techniques, we are developing new processes to convert sugars and oils to chemical products. This research is needed to produce chemical building blocks used in industrial and consumer products while avoiding the use of petroleum and production of unwanted byproducts. This research also is expected to lead to new families of chemical intermediates for products with properties not currently available from the petrochemical industry, such as biodegradability, recyclability, and other desirable attributes.

For more than a decade, our unique catalysts and catalyst support systems have proven to be robust and efficient in the wet, condensed-phase conditions where biomass typically reacts. These catalytic systems provide both higher activities and longer lifetimes than catalysts previously available. Our unique laboratories and instruments that leverage support from EERE, including a new Symyx combinatorial chemistry workstation, are important components of this capability. To support the growth in bio-based products research, we are planning a Bioproducts, Sciences, and Engineering Laboratory (Module 3.7).

Improved Processes for Fuels and Hydrogen

We have spent more than 30 years developing chemistry and chemical engineering expertise that is critical to DOE's biomass gasification and biopower program. We continue our contributions to the current synthesis gas program by developing and demonstrating innovative, breakthrough catalyst formulations and catalytic systems that significantly reduce the cost of producing bio-based fuels and chemical precursors using synthesis gas feedstocks. In particular, we are merging state-of-the-art technology in heterogeneous catalysis and micro-channel/micro-scale technology to provide the next generation of reactors for producing fuels from synthesis gases at a scale compatible with financially viable biomass operations. We are also using

our expertise in robust catalyst formulations to catalytically convert ligno-cellulosic biomass in aqueous solution, such as residues from dry-mill ethanol plants, to a methane-rich fuel gas. The technology also allows wastes such as bovine manure to be efficiently converted to energy products while alleviating environmental problems.

We are developing catalytic technologies that afford innovative, cost-effective routes to produce hydrogen from biomass, relying on signature strengths in catalysis and nanotechnology (Module 3.1.1). We are exploring how to convert biomass products (created as part of the sugars platform research) into hydrogen. These products serve as liquid hydrogen "carriers" that can safely and efficiently be transported to sites where hydrogen is needed. The catalytic reforming of these intermediate carrier products can generate hydrogen for a variety of uses. We also are examining basic biological pathways to create hydrogen directly from biomass resources through the use of microorganisms as even more efficient hydrogen production pathways for the future.

Chemicals and Products Research with Industry

We are a leading DOE laboratory for developing chemical intermediates and other industrial products in conjunction with industry partners via cost-shared projects enabled by Cooperative Research and Development Agreements. These projects focus on very early proof-of-concept research, rapid reduction of concept to practice, and clear demonstration of commercial viability for new technology. For example, our researchers, working in collaboration with Archer Daniels Midland and the National Corn Growers Association, developed processes that will reclaim greater value from the hull fiber that is removed from corn kernels during the first stages of corn milling and traditionally sold at cost as livestock feed. After less than two years of laboratory research, this process is now ready to be scaled up and will be demonstrated at the pilot scale during the next two years.

Scientists at PNNL used NMR spectrometry and other advanced technologies to determine the molecular components of corn fiber oil, an integral part of a joint research project with Archer Daniels Midland and the National Corn Growers Association. This team developed a new process to economically recover low-cost corn fiber and convert the carbohydrates and lipids from this fiber to ethanol, polyol chemicals, and specialty oils, plus a higher value livestock feed.

Program Support in Partnership with the National Bioenergy Center

PNNL is part of the National Bioenergy Center, which provides DOE with technical advice and program support to help guide planning and analysis efforts—such as the Office of the Biomass Program's Multiyear Technical Plan, Annual Operating Plan, and others—for the next generation of biofuel and bioproducts technologies. The National Bioenergy Center includes the National Renewable Energy Laboratory, Oak Ridge National Laboratory, Idaho National Engineering and Environmental Laboratory, and Argonne National Laboratory.

3.1.3.1 Bio-Based Products Initiative: Capabilities and Partnerships for Bio-Based Research and Products Development

Using a fundamental understanding of materials and catalyst formulation, complemented by innovative applications of emerging methods in molecular biology, PNNL's strong bio-based capabilities will uniquely serve the needs of the Office of Biomass Programs within EERE.

Through our Bio-Based Products Initiative, we are striving to integrate advanced chemical and biological science to establish a signature capability in developing these advanced processes for fuels and chemical intermediates.

Energy

Catalysis Capabilities

Building upon established capabilities in materials science and formulation of heterogeneous catalysts, PNNL is directing targeted capability-development investments to establish a fundamental understanding of the behavior of catalysts in aqueous conditions typical of biomass conversion reactions. Leveraging existing instruments for catalyst characterization and in situ evaluation of reaction kinetics, we have enabled the formulation of next-generation, robust and effective catalysts suitable for conditions associated with bio-based conversion processes. These conditions include condensed-phase, high-temperature, high-pressure, and extreme pH. In support of DOE program goals, we have successfully established a distinctive capability in formulating catalyst supports and catalyst materials to enable conversion of sugars, oils, and synthesis gases to fuels and chemicals.

Our strong capabilities in catalysis build upon the research described in Module 2.3.

Filamentous Fungi

In addition to chemical conversion processes, this initiative will establish us as a leader in discovery of novel filamentous fungi, as well as new molecular biology tools for "engineering" these organisms to enable specific biological processes. We apply methods such as proteomics and bio-informatics to unravel the genes associated with regulating optimal production characteristics, nutrient uptake, and protein expression and enzyme production.

Our strength related to genomic research and how this work leverages research supported by SC is described more fully in Module 2.2.1.

Partnerships and Collaborations

Through the Bio-Based Products Initiative, we are forming relationships with institutions—such as major grower associations, commodity processing companies, and chemical and energy companies with a commitment to renewable products—that support the EERE objectives. These partnerships ensure a focus on well-

defined outcomes for our research, provide a mechanism for cost-shared technology development and demonstration, and facilitate transfer of successful technology from the Laboratory to commercial deployment in the private sector, a principal goal of the DOE Office of Biomass Programs. Partnerships with the National Corn Growers Association, as well as several state grower associations, have already resulted in successful projects to move discoveries from the laboratory to the pilot demonstration scale. In the future, these partnerships will facilitate complete commercialization of these processes.

We also partner with other research institutions, particularly universities and other federal laboratories, to expand the breadth and depth of capability available to DOE in the bio-based products field. We are part of the National Bioenergy Center, a collaboration of DOE laboratories in the biomass area, including the National Renewable Energy Laboratory, the Idaho National Engineering and Environmental Laboratory, Oak Ridge National Laboratory, and Argonne National Laboratory. Our growing partnership with Washington State University (WSU) has resulted in several collaborative research projects and will lead to construction of a new, state-of-the-art, multiuser Bioproducts, Sciences, and Engineering Laboratory at the WSU Tri-Cities campus, to be shared by PNNL and WSU researchers. Design and construction of this new laboratory will be funded by Washington State, with PNNL providing significant technical support throughout design and installation of key instrumentation (Module 3.7). This shared facility will dramatically enhance our ability, along with our partners, to conduct biomass conversion research, and will provide WSU with greatly expanded laboratory and teaching space, affording an opportunity to develop a new graduate program in bioproducts science and applied biotechnology at WSU.

Battelle, as operator of PNNL, places a priority upon bridging discoveries at the laboratory bench to commercial deployment of the technologies that can result from this research. With its many industrial partners, Battelle provides an important avenue for transferring technology from the laboratory to the commercial sector. Complete development of bio-based product technology has been the focus of significant investment by Battelle in recent years, and PNNL technology will continue to benefit from Battelle commercialization investment.

The Bio-Based Products Initiative will focus its capabilities in fungal biotechnology to develop the next generation of biological catalysis technologies for producing industrial products in biorefineries.

Examples of recent Bio-Based Products Initiative accomplishments:

- Receiving FY 2003 funding for a second phase of development to advance the corn fiber separation and conversion process (jointly developed by PNNL and Archer Daniels Midland) to a pilot-scale demonstration in conjunction with the National Corn Growers Association.
- Receiving capital funds to procure a custom-developed Symyx combinatorial chemistry system that will significantly enhance PNNL's ability to develop and test new catalyst formulations for bio-based product development.
- Receipt of the Society of Industrial Microbiology's Charles Porter Award by one of PNNL's staff scientists who works in the growing area of bio-based products and who conducts research related to filamentous fungi.

3.1.4 Improving Energy Efficiency Through Building Operation, Energy Codes, Market Transformation, and New Technologies

PNNL's Buildings Program reduces the energy intensity of our nation's buildings, while providing for the occupants' security, health, and productivity.

Our core DOE Buildings business includes energy codes and standards, operations and maintenance, market transformation, and technology demonstration and deployment. In addition to our ongoing support to EERE in these areas, we will broaden our contributions to include:

- R&D of organic light-emitting diode (OLED) technology, a component of solid-state lighting research
- development of advanced building diagnostics and controls, a near- to mid-term effort to develop and apply technology to reduce the energy intensity of buildings and enable management of peak energy demand.

Achieving these two goals increases the S&T content of our EERE business and, in the case of OLED technology, enables us to apply our fundamental science expertise and capabilities to the development and application of a new lighting technology.

We have the capabilities and laboratory facilities necessary to lead development of the OLED technology component of EERE's Solid-State Lighting Program, including materials design and synthesis, thin film deposition and modeling, and molecular structure testing. OLED technology has the potential to transform lighting practices in homes and buildings, and because of its distributed nature, could lead to a 50 percent reduction in energy used for lighting.

Ongoing Projects

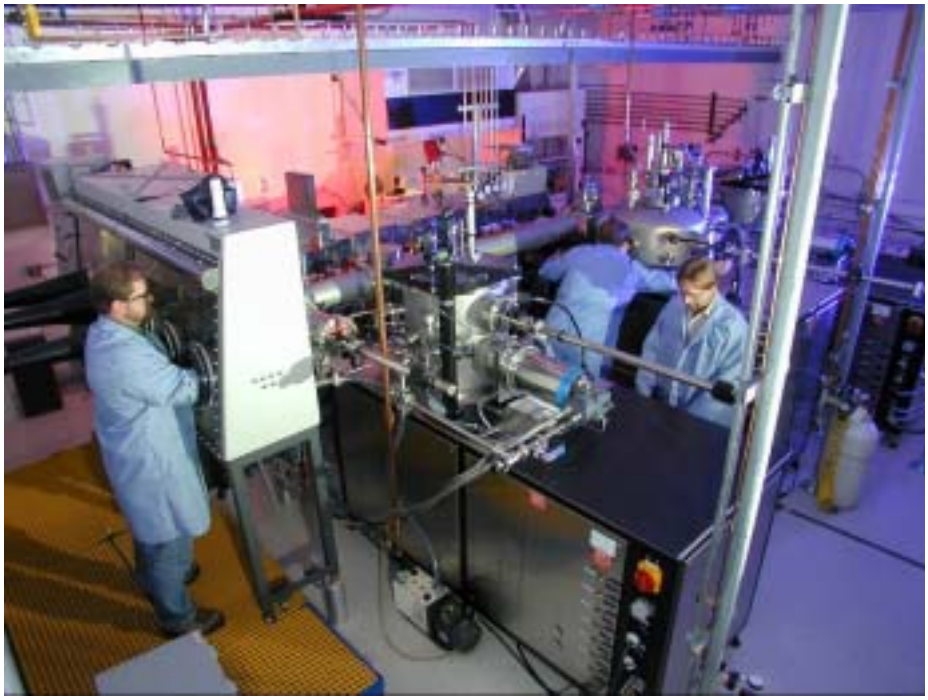
In the area of Automated Building Diagnostics and Controls, we develop advanced technologies that enable real-time building and equipment condition monitoring. These technologies ensure cost-effective, energy-efficient building operation and maintenance that also minimizes environmental impacts and creates a secure, healthy, productive indoor environment. Our work in automated building diagnostics and controls builds on our long-standing competency in building operations, which has led to the deployment of technologies in both the public and commercial sectors and positions us to provide significant contributions in the future. Our latest activities focus on applications of wireless technology, development of low-cost sensors, and development and application of diagnostic tools that facilitate energy and environmental management of commercial and residential buildings.

Energy

PNNL contributes significantly to the mission of DOE's EERE and to its Building Technologies, Weatherization and Intergovernmental, and Federal Energy Management Program offices as well as the Planning, Budget Formulation, and Analysis Group within EERE's Business Administration Office. PNNL's Buildings Program also provides significant technology application and deployment services to other federal agencies, such as the General Services Administration, Army, and Marine Corps, to help them meet energy reduction goals mandated by the Energy Policy Act of 1992 and amended by subsequent Executive Orders.

We play a significant role in improving building energy efficiency by supporting stronger building energy codes, including their adoption, implementation, and enforcement, as well as market transformation and technology demonstration and deployment. Through the Building Energy Codes projects, we assist DOE in developing and applying new and enhanced building energy codes and building practices that enable the use of new energy-efficient technologies and practices. Similarly, through our Building Energy Code Implementation projects, we work on behalf of DOE with government agencies, state and local jurisdictions, national code organizations, and industry to encourage the construction and retrofit of energy-efficient buildings. And through our Market Transformation projects, we collaborate with DOE and industry partners to develop and implement programs to create and stimulate viable markets for new energy-efficient products.

Through this suite of projects, which includes technology demonstration and deployment, we help speed the adoption and implementation of building energy codes and the deployment of energy-efficient technologies to a wide range of customers and stakeholders including federal agencies, state and local governments, and international agencies.



PNNL is conducting thin film research to develop OLED technology in the pursuit of revolutionary low-cost, efficient lighting.

3.2 Supporting Electric Transmission and Distribution Reliability

As a major resource in the national effort to safely, efficiently, and reliably meet the electricity needs of the United States, PNNL is applying multidisciplinary capabilities to all aspects of the energy system, from generation to transmission, distribution, and end use of electricity.

We are supporting the newly created OETD in two primary areas—transmission reliability and electric distribution transformation. Aligned with this new office's goals, our research, development, and demonstration projects will enhance the electricity delivery system to ensure economic and national security. Our technical leadership in real-time systems analysis, large-scale power systems modeling, and advanced sensors is recognized by industry and valued by DOE. Combined with our understanding of competitive markets, regulatory frameworks, and demand response programs, we are creating a new paradigm that will transform the energy delivery infrastructure of the future.

Energy

Transmission Reliability

We are applying strengths in simulation, measurement, and analysis to help determine factors that may cause the national electrical transmission system to break down—and ensure the system does not reach those breaking points. Our transmission reliability research and technology development focuses on understanding and managing the behavior of the electrical system in the areas of automatic controls, system operations, and planning.

The DOE Transmission Reliability Program and the ongoing Wide Area Measurements System (WAMS) effort provide a general framework for these activities. This effort is specifically designed to meet the information needs of the changing power system, with a strong focus upon sharing federally owned knowledge and technology that is critical to ensuring reliability.

With support from the DOE Transmission Reliability Program, WAMS is now being extended into the Eastern Interconnection. The suite of measurement technologies and associated information analysis tools enables better decisions and insight into highly complex grid behavior that is undetectable with conventional technology. We will continue to address model validation and calibration as part of this program and its expansion to new regional transmission systems. In addition, we will continue to develop and analyze tools for grid management and conduct research related to demand response as a member of the Consortium for Electric Reliability Technology Solutions, in support of the DOE Transmission Reliability Program.

Electric Distribution Transformation

We support OETD with its program to develop a communications and controls environment that will enable transformational change in electric services. The inception of the program has been significantly influenced by PNNL's Energy Systems

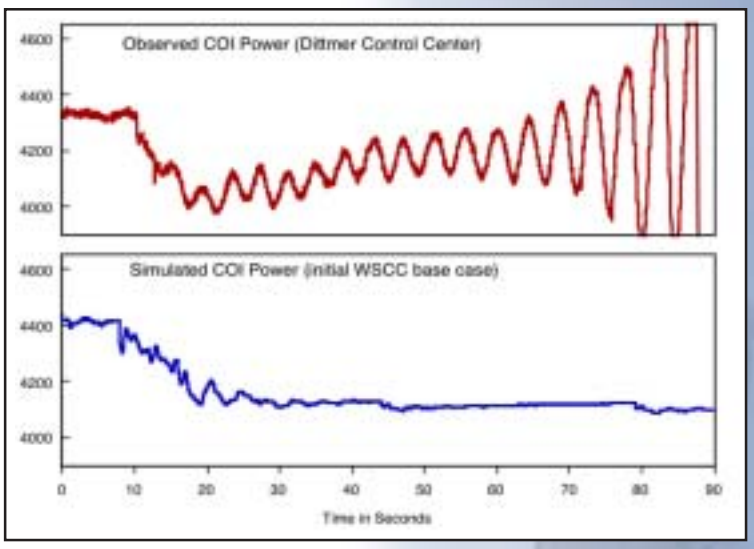
Transformation Initiative (ESTI) efforts (Module 3.2.1). The program builds on internally funded research, and the resulting GridWise vision. In particular, using highly accessible telecommunications and information technology will enable value to be communicated transparently throughout the electric system. Better communication of value and data will facilitate participation of distributed energy resources (specifically distributed generation, storage, and load), permit active customer (and equipment) response and market participation, and enable more stable energy markets. Overall, the energy system will become more responsive, robust, secure, and reliable as a result.

PNNL is a founding member and vision leader for the WAMS effort, which is designed to meet the information needs of the changing power system.

Specific activities to support this transformation include assessing integration issues resulting from distributed energy resource technologies from multiple vendors in the distribution system and testing the technical and economic impacts of large numbers of these devices on the distribution system and transmission network. We also will explore the institutional, business, and policy issues associated with adopting advanced communications and controls systems. Architectures to empower all stakeholders (producers, consumers, distributors, and regulators) to respond to market prices and system constraints will be established through open communication and control architectures.

Our leadership in this program includes the following five areas:

- **Architecture** – Establish the technical and economic framework for a distributed electrical and business environment.
- **Applications** – Develop new functions and capabilities for the energy system through transformational technologies.
- **Simulation and Analysis** – Hypothesize, study, and predict the impacts of implementing transforming strategies and technologies that model physical, market, and regulatory aspects.
- **Test Beds and Demonstrations** – Gain insight into the issues and requirements of implementing transformational concepts and facilitate their early adoption.
- **Stakeholder Engagement** – Engage stakeholders in examination and advancement of transformational concepts to ensure all potentially affected or interested parties are informed and have the opportunity to participate.



These graphs show the difference between measured and simulated grid performance during the August 10, 1996, western grid breakup.

3.2.1 ESTI: Bringing the Electric Grid into the Information Age

PNNL's vision of the energy system of the future includes creating a collaborative network embedded with real-time information and intelligence that integrates supply, demand, transmission, and distribution with new "plug-and-play" technologies, distributed generation, energy storage, and customer load management.

The ESTI is investing in research that will enable physical devices, commercial instruments, and public/private organizations to collaborate through advanced forms of information exchange, optimizing the energy system to address the economic, environmental, and national security needs of our society.

GridWise: A Vision for Future Energy Systems

While the term GridWise has been coined to represent a key ingredient of the intelligent grid of the future, the ESTI represents our internal investments in this area. We are developing industry relationships as well as engaging regional and national interests in the creation of the GridWise vision. The GridWise Alliance is being established to characterize and communicate the societal benefits of transforming the electric infrastructure, encourage interaction to develop synergistic commercial benefits, and accelerate the technical and regulatory transformations necessary to advance these concepts. This group includes industry leaders such as Sempra Energy Solutions, PJM Interconnection LLC, Alstom Esca Corporation, IBM Global Energy & Utilities Industry, and the Rockport Group, and indicates early support of our concepts by industry.

Our internal investments are building the basic long-term science foundation needed to support the transformation of the energy system, including capabilities in energy systems simulation, analysis, and controls. This work includes computer simulation tools that link economic market operations with the physical operation of the power system at both the retail/distribution and wholesale/transmission levels. Basic science is also being conducted to research new decision algorithms for analyzing optimal control of linked physical and economic systems, as well as a macro-level theory of transactive control that models the collective behavior of the vast numbers of interactions involved in such a complex system.

Technological Considerations

Our GridWise vision shapes a new era of energy commerce that allows transaction-based decisions to drive operations and planning at all levels of the system. The architecture to support the necessary communications reliably, securely, and with due consideration for privacy, must be scalable, resistant to failure and attack, and flexible enough to evolve as better technological solutions emerge. These requirements are not wholly unique to the energy industry, but are found in many sectors of commerce. This initiative foresees solutions that involve adapting and influencing mainstream information technology approaches to deliver an electric energy infrastructure in step with the architecture of the nation's economy in general.

Energy

GridWise™ concepts have served as a compelling vehicle for establishing a set of new activities in the Electricity Distribution Transformation Program within DOE's new Office of Electric Transmission and Distribution.

The crosscutting aspect of the initiative engages Laboratory-wide capabilities and creates opportunities for national and homeland security programs related to protecting the nation's critical infrastructure. It also creates opportunities in other areas of DOE, including EERE, by looking at how fuel cells and other distributed resources can be integrated into the energy system of the future, and FE, with the potential for designing smart energy infrastructure that could affect fossil energy generation plants or account for carbon "trading" if that concept becomes a reality.

PNNL engineers are designing smart chips that can be fitted into household appliances to continually monitor the power grid for energy fluctuations. When the grid is under stress, a grid-friendly appliance would identify these fluctuations and, within milliseconds, automatically shut down for a short period of time to give operators time to stabilize the system.

Examples of recent ESTI accomplishments:

- Providing the vision and leadership for a national program within DOE's newly formed Office of Electric Transmission and Distribution.
- Maintaining two key advisory groups: the ESTI peer review committee and the CEO Coalition's GridWise Alliance Board, which includes numerous industry leaders.
- Hosting the third Communications and Control Systems Distributed Energy Conference in 2002.

Energy

3.3 Developing Clean and Efficient Fossil-Based Power and Hydrogen

PNNL is developing innovative technologies that will support development of the world's first fossil-fuel-based, pollution-free power plant and enable the transition to the hydrogen economy.

By 2015, FE is striving to design, construct, and operate a 275-megawatt prototype power plant that produces electricity and hydrogen with near-zero emissions. Virtually every aspect of this cutting-edge plant, known as FutureGen, will incorporate state-of-the-art technologies including fuel cells, hybrid energy systems, and techniques for coal gasification and carbon sequestration. Our R&D of fossil-based power and hydrogen generation systems will play a critical role in FutureGen and DOE's vision to use existing supplies of fossil fuels in a cost-effective and efficient manner and with minimal environmental impacts. With capabilities in solid oxide fuel cell technology, materials science, surface chemistry, catalysis, electrochemistry, and carbon sequestration, we will help identify and address the technical barriers necessary for FutureGen to become a reality.

Solid Oxide Fuel Cells

As a leader in solid oxide fuel cell technologies, we are providing problem-solving research to optimize fuel cell systems and address the technical and economical challenges to commercialization of these systems for stationary, transportation, and military applications (Module 3.3.1). The modular fuel cells developed as part of SECA—managed by PNNL and the National Energy Technology Laboratory (NETL)—will become the basis of the FutureGen plant.

High-Temperature Electrochemistry Center

Through management of and participation in the High-Temperature Electrochemistry Center, we are collaborating with NETL and universities to provide crosscutting multidisciplinary research aimed at developing the advanced electrochemical technologies necessary to integrate the many components of FutureGen.

We conduct the majority of the center's core research with emphasis on electric performance, thermoelectric materials, regenerable fuel cells, membranes, and sensors. In 2002, Montana State University was identified as a satellite research center with a focus on deposition of metal oxide thin films and electrical reactions at buried interfaces. Additional universities will be added as satellite centers focusing on specific topical areas or disciplines where new scientific knowledge and innovation are needed to support FutureGen. These university partnerships also create opportunities for student internships and visiting scientists—helping develop scientific resources for solving the energy generation challenges of the future.

Carbon Management

Our Carbon Management Initiative (Module 3.4) is focused on developing the science that will lead to technologies for capturing and sequestering carbon. These technologies will be coupled with new systems to generate energy and hydrogen as part of FutureGen. Building on capabilities derived from waste treatment activities at the Hanford Site, we are applying our geochemical expertise to build an understanding of how to capture and contain carbon dioxide and assess its effect on the surrounding geology and hydrology.

We have the lead for technical integration in the newly established Midwest Regional Carbon Partnership (RCP), located in the heart of U.S. coal country. The Midwest RCP is one of nine national partnerships.

PNNL's participation in the High-Temperature Electrochemistry Center will help provide the technical underpinnings for fuel cell systems, turbines, and hybrid energy systems in support of developing large, land-based energy plants that are efficient, economical, and fuel flexible while producing near-zero emissions.

Energy

3.3.1 Advances in Solid Oxide Fuel Cell Technologies

Through its leadership in SECA and solid oxide fuel-cell R&D, PNNL will play a critical role in helping reduce the cost of modular solid oxide fuel cells for multiple applications to $400 per kilowatt by 2010.

SECA is a public-private alliance focused on making high-efficiency, low-cost fuel cells commercially available for a variety of applications. We jointly manage the alliance with NETL. Together, these laboratories coordinate solid oxide fuel-cell R&D to help FE achieve its mission to reduce dependence on imported oil and to mitigate environmental concerns associated with current methods of generating electricity from fossil fuels. We lead SECA's Core Technology Program, which is focused on addressing technical barriers identified by the program's industrial teams. Results from our research conducted as part of the Core Technology Program are shared with all the industrial teams to help advance their individual approaches to meeting the program's overarching performance, size, and cost goals.

Our areas of research in support of the SECA program include materials and manufacturing, modeling and simulation, fuel reformation, and thermal management. We are well suited to tackle these technical challenges because we can assemble multidisciplinary teams with expertise in:

- analytical and physical chemistry
- chemical separations and conversion
- computational science and engineering
- design and manufacturing engineering
- electrochemistry
- energy technology and management
- materials S&T
- microengineering and nanoengineering.

Our researchers are developing computational models at the stack and systems levels that simulate operation of a total system, assisting in component design, studying schemes for fuel and oxygen delivery, optimizing plate configurations within a multiple stack, and building a better understanding of operating parameters. Based on a long history of materials research related to solid oxide fuel cells, our researchers also are improving electrolytes and electrical performance, developing new cathodes, increasing anode strength, advancing and improving seals, and minimizing thermal stress. In addition to reducing cost, this research will lead to increased efficiency, durability, and performance, as well as reduced start-up times.

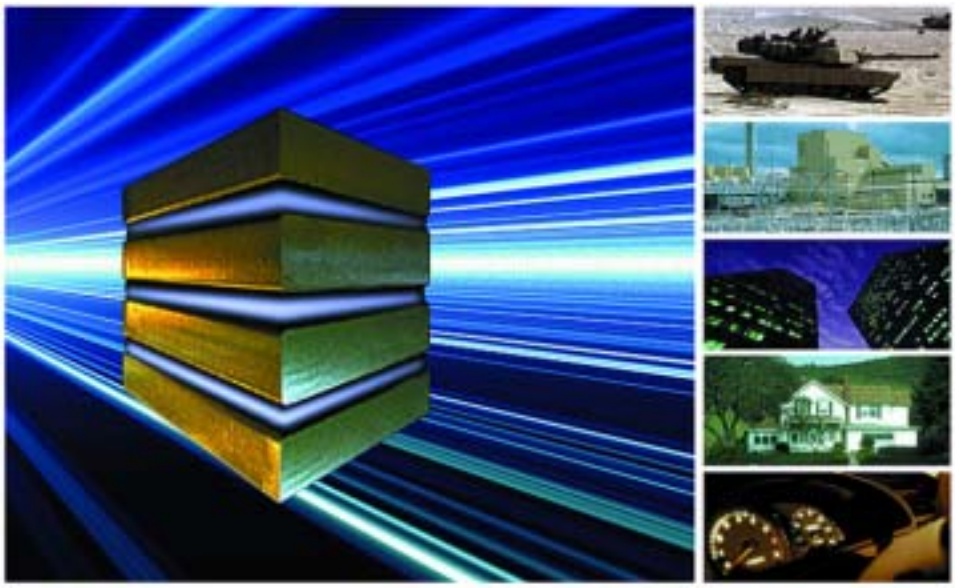
SECA's six industrial teams, including two new teams added in FY 2003, are pursuing a 2005 goal to develop 3 to 10 kilowatt solid oxide fuel-cell prototypes that would cost $800 per kilowatt when mass produced. By 2010, SECA targets $400 per kilowatt systems in commercial applications. These ambitious goals are aligned with FE's FutureGen Initiative, a $10 billion effort to build by 2015 a next-

generation power plant that operates on gasified coal and produces electricity and hydrogen while sequestering carbon for near-zero emissions (Module 3.4). Along with other SECA members, we will focus on developing large fuel cell clusters that use coal and coal gasification techniques to produce hydrogen and electricity in support of DOE's FutureGen vision.

Solid oxide fuel cells that meet the size, performance, and cost targets of SECA are providing the building blocks for other national programs. EERE's 21st Century Truck Program is focused on using fuel cells for auxiliary power systems and essential power systems in heavy trucks. The program concept adapts the SECA fuel cell for use on diesel-powered heavy vehicles. Using fuel cells to provide auxiliary power for heavy trucks instead of belt-driven generators powered by the engine will increase fuel efficiency and reduce emissions dramatically. Auxiliary power systems would eliminate the need for trucks to idle in order to maintain the necessary power for heating the diesel engine and sleeper cab and electronics.

The SECA fuel cell serves as the foundation for a program with NASA to adapt solid oxide fuel cells for aviation purposes. This program kicks off in FY 2003 and will first explore the use of solid oxide fuel cells for auxiliary power in commercial aircraft and may eventually consider their use for aircraft propulsion.

PNNL will build on its parent relationship with Battelle to bridge discoveries related to fuel cells to commercial deployment. For example, researchers at PNNL do some of the R&D for one of the SECA industrial teams—the Delphi-Battelle team. We have processes and procedures in place to ensure that any potential conflicts of interest are avoided and that DOE work receives first priority. At the same time, this relationship helps move technologies into the marketplace where they can begin making an impact in increasing efficiency and reducing emissions, consistent with DOE's energy and technology transfer missions.



PNNL, through its leadership of SECA and the alliance's Core Technology Program, is developing solid oxide fuel cells that can generate electricity from traditional fuels for a wide variety of applications.

3.4 Furthering Capabilities and Partnerships Through the Carbon Management Initiative

The Carbon Management Initiative seeks to establish PNNL as the DOE laboratory that has most profoundly shaped the nation's approach to addressing climate change, while simultaneously developing new science and technology programs.

Signature Areas

To achieve our desired level of impact, we will emphasize three signature contributions:

1. Building the basic scientific understanding of climate change phenomena and ecosystem impacts.
2. Developing computational tools and techniques for evaluating alternative strategies for managing the potential risks of climate change.
3. Developing and deploying technological solutions to address climate change.

Energy

Through our work in areas such as the ARM Program and regional climate impact modeling, we have already made significant strides in *understanding climate change*. As a result, the majority of the Carbon Management Initiative's investment resources will be devoted to developing computational tools and techniques, and developing and deploying technological solutions.

Tools and Techniques

Our investment in this signature area will focus primarily on delivering analytical tools that will provide valuable information to DOE's newly created Climate Change Technology Program Office and its strategic planning process. This new office is intended to coordinate implementation of the President's Climate Change Technology Initiative with the Department of Commerce, which coordinates the President's Climate Change Science Initiative. By applying the integrated assessment modeling capabilities developed with support from SC to both presidential initiatives, we can be an analytical leader and profoundly increase our national impact. These efforts also will position PNNL's Joint Global Change Research Institute, a collaboration with the University of Maryland, for expanded programmatic support. With increased support, the resources of the institute will become more widely available to support DOE's needs.

The Carbon Management Initiative also supports the efforts of FE, which is looking toward carbon capture and sequestration technologies for its next-generation energy plants.

Technological Solutions

This third signature area will focus on carbon dioxide (CO_2) capture, sequestration, and monitoring and will receive the majority of the initiative's investment, including nearly all capability-development investments.

In the area of CO_2 capture, we are focused on novel technologies that have the potential to separate CO_2 from power plant and industrial flue gases at a significantly lower cost than today's amine-based systems. The use of nanomaterials offers exciting possibilities for novel separation processes due to the tremendous

potential in preparing chemically selective solids with exceptionally high surface area. To be effective, however, there is a critical need to characterize the uptake of chemicals in such nanomaterials and to understand their chemical selectivity and other properties of interest for capturing CO_2. Targeting this area also allows the Carbon Management Initiative to leverage investments made by the Nanoscience and Technology Initiative (Module 2.5.3).

With respect to sequestration, we are examining geologic sequestration in three types of formations: deep-sedimentary, saline-filled formations; deep-basalt, saline-filled formations; and gas hydrate-bearing formations. Deep-sedimentary formations are the most prevalent in the United States and the likely choice for the nation's first large-scale sequestration demonstration. Our work will develop a better understanding of the mixing behavior of supercritical CO_2 in brine-filled porous media and the long-term effects of exposure to high-pressure CO_2 on the physical, chemical, and mechanical properties of caprocks. We will also develop new capabilities for studying the behavior and effects of supercritical CO_2 in sedimentary rock formations.

While basalt formations are not as widely available, their geochemical composition offers the unique ability to mineralize CO_2 in situ, chemically trapping the CO_2 permanently. Building upon our extensive knowledge of Columbia Basin basalts, this work will determine the rate of CO_2 consumption by chemical reaction with selected basalt rocks under realistic conditions of pressure and temperature. Our goal is to better understand which primary minerals in the basalt react preferentially with dissolved CO_2 and to identify any surface-armoring reactions that could slow the kinetics of the mineralization process.

Permanent sequestration of CO_2 in methane hydrate-bearing formations while simultaneously producing methane offers a unique sequestration strategy that co-produces a valuable product. We will focus on understanding how a real gas injection and extraction process would or could work in porous media. To support this work, we have obtained natural hydrate-bearing core samples from the Canadian Arctic and from the Hydrate Ridge off the coast of Oregon. Researchers will characterize the physical and chemical properties of these samples through a combination of experimental measurements. We also will conduct injection dynamics experiments with these samples to ascertain the effectiveness of using CO_2 to dissociate the gas hydrate and recover the methane while permanently sequestering the injected CO_2 as a hydrate.

In the area of CO_2 monitoring, we are focused on novel, low-cost sensors and tracers that can be used to understand the fate of injected CO_2. The relatively high background levels of CO_2 in the atmosphere and soil, coupled with seasonal and diurnal variability, make it extremely difficult if not impossible to immediately detect small CO_2 leakage rates with existing technology. We will explore chemical and radiological tracers suitable for monitoring leakage of CO_2 from deep geologic formations. Two types of sensors will be developed for detecting the selected tracers: a laser photoacoustic spectroscopic sensor and a scintillating-grid radiometric gas sensor. The sensors will be evaluated for potential use in a future field demonstration.

Examples of recent Carbon Management Initiative accomplishments:

- Co-founding (with nine universities) a terrestrial carbon sequestration R&D center funded by the U.S. Department of Agriculture.
- Providing the supporting science for DOE's largest U.S.-based geologic sequestration project, as part of a public-private partnership.
- Continuing pioneering work on in situ mineralization of CO_2 and simultaneous sequestration/methane hydrate production through several newly established DOE-funded projects.

PNNL researchers are conducting groundbreaking research to reduce atmospheric CO_2 emissions to levels that will prevent global warming. As part of this research, scientists are testing a unique method aimed at harvesting methane gas from frozen hydrates. The concept involves using CO_2 to "unfreeze" the methane hydrate to release methane gas. If successful, CO_2—a greenhouse gas—would remain deep underground as solid CO_2-hydrate while simultaneously producing methane gas for the natural gas market.

3.5 An Integrated Approach to Nuclear S&T

We are integrating our nuclear S&T portfolio to address concerns related to national security, legacy environmental challenges, and options for energy generation that reduce both dependence on energy imports and greenhouse gas emissions.

For decades, DOE has been the center of the nation's nuclear research and we have been a part of the R&D infrastructure that has enabled DOE to meet national needs related to nuclear energy, environmental management, international nuclear safety, and national defense and homeland security. With a long history of nuclear S&T expertise and a national reputation in radiation detection, nuclear fuels, and materials, our integrated nuclear strategy focuses on identifying areas of strength and enhancement needed to ensure that we can continue supporting DOE in the future.

Energy

National Defense and Homeland Security

Based on growing national needs, we anticipate significant programmatic growth in national defense and homeland security applications of our nuclear S&T capabilities (Modules 4.1–4.1.6). We also are making internal investments to establish Radiological Detection and Analysis Laboratories (RDAL) that will make these key capabilities more accessible (Module 3.5.1).

Advanced Energy Concepts

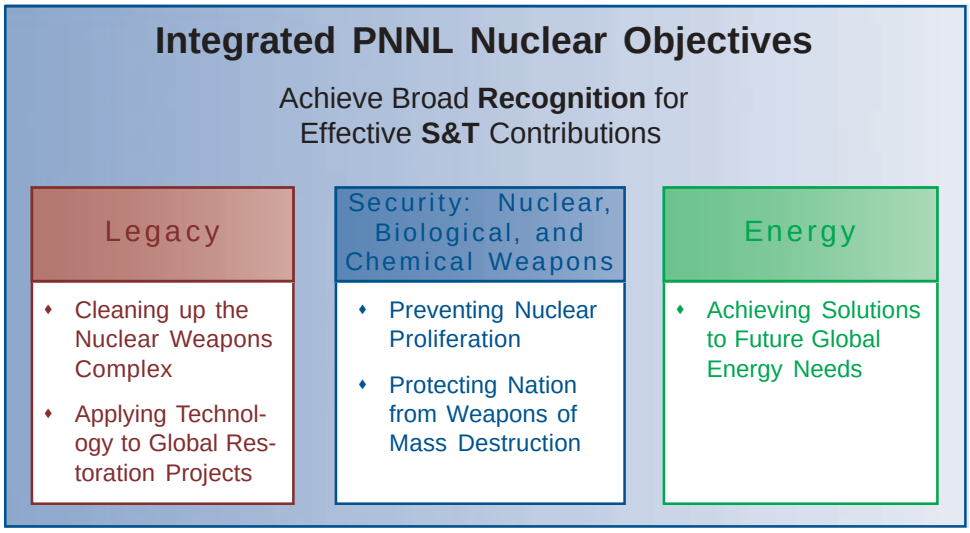
We intend to work with other laboratories to support DOE's development of advanced reactors and fuel cycles, including playing a role in developing next-generation power reactors that are economic, safe, and proliferation-resistant, and are capable of becoming the base, advanced energy source to support a hydrogen economy. We will also focus on specialized energy sources, such as space power for national security, intelligence, and defense. While we do not expect significant near-term growth from NE, we will focus on maintaining our efforts related to space power, radioisotopes, the National Energy Research Initiative, and the International Nuclear Energy Research Initiative, as well as promoting nuclear education in support of our nuclear science and technology needs. These efforts are supported by our core capabilities in nuclear materials, including irradiation performance and structural performance, nuclear chemistry and advanced separations technology, and advanced diagnostics and prognostics.

Environmental Legacy

We apply our nuclear capabilities to provide cleanup solutions for areas contaminated during nuclear weapons production (Module 5.1).

Critical Capabilities

To make the nuclear S&T resources broadly valuable to DOE, we must recruit and retain critical staff in nuclear S&T and maintain specialized facilities and equipment. This includes replacing essential capabilities currently housed in facilities in the 300 Area. These capabilities will support expected radiological R&D involving ultralow-level through high-level radioactive materials (Modules 3.7 and 7.3).



Taking an integrated approach to PNNL's nuclear S&T enables us to leverage Laboratory capabilities across three major customer needs: legacy and environmental issues; national security interests related to nuclear, biological, and chemical weapons; and advanced energy systems.

As a result of the integrated nuclear strategy developed in FY 2003, we have a solid basis for managing staffing, facilities, programs, and S&T capabilities that support our customers:

- Office of Science (SC) (2.0)
- Intelligence (IN) (4.4)
- Office of Nuclear Energy, Science, and Technology
- Office of Environmental Management (EM) (5.0)
- Office of Civilian Radioactive Waste Management
- National Nuclear Security Administration (NNSA) (4.1)
- Department of Homeland Security (DHS) (4.5)
- Defense Threat Reduction Agency
- Defense Advanced Research Projects Agency
- NRC (3.6)
- U.S. Department of Defense (DoD) (4.6)

Energy

3.5.1 Enhancing Nuclear S&T Capabilities

We are ensuring that our nuclear S&T capabilities are available to respond to the broad spectrum of needs identified by our customers.

Maintaining and enhancing our nuclear S&T capabilities, collaborations, and infrastructures are necessary to meet long-term needs for DOE's related nuclear missions. We are committed to maintaining and adopting nuclear technical capabilities to address challenges in homeland security, legacy environmental issues, and energy production.

The focus of this crosscutting effort is on those areas that contribute most to DOE's mission and laboratory vision. We intend to become the preferred source for radiological detection and analysis capabilities for the development, evaluation, and deployment of effective nuclear and radiological sensing instruments and systems to meet broad customer needs.

Establishing Radiological Detection and Analysis Laboratories

We perform R&D to provide novel technologies for rapid, automated trace detection and analysis of sensitive materials. By developing and integrating a suite of advanced capabilities in this area, our Radiological Detection and Analysis Laboratories (RDAL) will enhance our ability to provide radiological detection and analysis to many areas within DOE as well as other government agencies.

This effort will be structured to allow project managers to undertake interdisciplinary projects and use the diverse resources as needed to meet client project requirements. Overall, these laboratories will increase visibility and access for capabilities and will further strengthen capabilities by promoting teaming with universities, industry, and other government agencies. Collaborating with universities will enhance the supply of qualified staff in this area available to PNNL and other laboratories within the DOE complex.

Instrumentation capabilities within these laboratories can be deployed in interdisciplinary, multisensor systems, such as "portal measurement systems" to give enhanced border security and in meeting test and measurement needs to support programs in the National Nuclear Security Administration and Defense Programs.

Detecting and Preventing Nuclear Threats

In FY 2004 and beyond, new trace analytical capabilities will be developed to prevent and detect proliferation of weapons of mass destruction. Examples of internal research related to nuclear nonproliferation and attribution include a project for advanced and automated radiochemical analysis and another on electrode structures for high-pressure xenon detectors.

Building Radiochemical Processing Capability for Environmental Management

Advanced actinide separations technologies and the behavior of actinides in the environment are two areas of development. The benefits of advanced actinide separations technologies include reduced cleanup costs, reduced amounts of waste requiring disposal, and recycle of useful isotopes. Research challenges include aqueous separations for waste volume reduction and the transmutation of waste for nuclear reprocessing applications. These breakthroughs will accelerate the environmental cleanup of nuclear wastes at the Hanford Site and enable us to make contributions to waste cleanup and environmental restoration challenges worldwide, including the characterization of contaminated sites, monitoring of remediation and disposal facilities, and sensing technology for process monitoring and control.

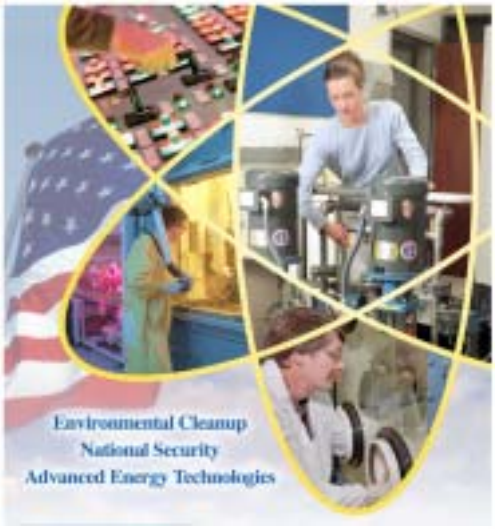
Supporting Nuclear Energy Plants

This effort supports nuclear energy by developing S&T for the current and next-generation nuclear systems that would serve as a major power source to produce hydrogen along with clean fossil and renewable energy options. We are currently seeking knowledge in two areas that support the needs of the NRC: 1) the life-limiting degradation of light-water reactor materials and components and 2) the development of diagnostic and prognostic tools for advanced reactors (Module 3.6). These efforts will help extend the lives of reactors and improve operational effectiveness and safety.

Maintaining Critical Resources

The Laboratory is committed to building and sustaining critical capabilities needed to support DOE's missions.

Continuing to make critical nuclear S&T resources available to DOE will require retaining and enhancing strong nuclear science and engineering capabilities. Establishing the RDAL, and coordinating this with a strengthening of our sensors and electronics capabilities, is an essential component in our facilty strategy (Module 7.3).



We are building critical capabilities in nuclear S&T to solve problems in cleanup and national security.

Examples of recent nuclear S&T accomplishments:

- Refocusing FY 2003 efforts on the nuclear component of national and global security—areas where significant needs exist.
- Hosting the 40th DOE Weapons Agencies NDT Organization meeting, which resulted in proposals for target characterization studies to support the National Nuclear Security Administration and an invitation to participate in development of the Advanced Non-Destructive Engineering Strategy for the Nuclear Weapons Complex.
- Preparation of "Nuclear Technology Paths Towards Carbon-Free Energy" for publication; this led to a proposal to the Office of Nuclear Energy, S&T.
- Investigating the fundamental aspects of radiation-induced degradation of materials to support material evaluation needs for extending the licenses of power nuclear reactors.

Energy

3.6 Energy-Related R&D for Others

The energy-related R&D PNNL conducts for other government and private clients applies capabilities developed by DOE to solve national needs and enhances the resources and capabilities available to DOE in the future.

U.S. Nuclear Regulatory Commission

We fulfill DOE's commitment to the NRC to provide world-class technical capabilities from the national laboratories in support of the NRC's nuclear safety mission. Our work for the NRC addresses nuclear fuels, nuclear reactor pressure boundary materials, nuclear materials characterization, environmental transport of radionuclides, spent fuel storage and transportation, operating plant license extensions, nuclear facility safety, regulatory criteria development, and international regulatory program development. We provide NRC with internationally recognized experts in nuclear fuel burn-up and nondestructive examination analyses.

We support the three major divisions of the NRC:

- The Office of Nuclear Reactor and Regulation, which is responsible for ensuring public health and safety through licensing and inspection activities at all nuclear power reactor facilities in the United States.
- The Office of Nuclear Regulatory Research, which plans, recommends, and implements programs of nuclear regulatory research. We contribute our expertise in nondestructive evaluation of reactor vessel materials and in nuclear fuels performance assessments to meet this office's needs.
- The Office of Nuclear Material Safety and Safeguards, which focuses on public health and safety through licensing, inspection, and environmental reviews for all activities regulated by the NRC except operating power and nonpower reactors.

Overall, our work for the NRC supports the continued operation of 103 nuclear plants that provide approximately 20 percent of the nation's electricity—the equivalent of millions of barrels of oil.

National Aeronautics and Space Administration

From basic research to developing specific solutions relating to energy technologies, environmental technologies, and climate physics, we support NASA missions that relate closely to DOE mission areas. We intend to focus on the following areas of research and development for NASA:

- Developing new applications of microtechnology for NASA space missions including fuel production for Mars missions.
- Developing new nuclear space power systems.

- Developing fuel cell systems for commercial aircraft, in collaboration with NASA's Glenn Research Center (Module 3.3.1.)
  - Support for NASA's Earth Science Enterprise in areas of climate and atmospheric chemistry modeling and in the application of NASA satellite instruments that support the ARM Program's research objectives, which include research on clouds, aerosols, and climate; use of satellite-based remote sensing in climate research; and applications of remote sensing to natural resource assessment.

Bonneville Power Administration

Our strategic research with BPA regarding energy system reliability and environmental compliance has led to real-time grid monitoring that is integral to DOE's new OETD (Module 3.2). Our environmental support includes fishery science that helps ensure sustainable operation of the hydropower system in the Pacific Northwest.

Commercial Energy

Our researchers apply their capabilities to commercial R&D for nongovernment clients in areas including nuclear materials safety, advanced clean power generation concepts, next-generation power systems, and low-emission vehicle technologies.

We work with automotive manufacturers and automotive equipment manufacturers to explore lightweight materials, exhaust aftertreatment technologies, and solid oxide fuel cells for use in auxiliary power systems for heavy trucks and aircraft.

In another example, we are supporting efforts to reduce energy use at the nation's military bases by installing monitoring and diagnostic technologies as well as performing energy audits to determine opportunities for energy efficiency improvements.

These efforts help move government advances into real-world applications where they can benefit the environment, energy efficiency, and the nation's economy. We also work with commercial firms to establish major public-private partnerships in DOE areas of interest such as carbon management and low-emission vehicles.

PNNL's development of Decision Support for Operations and Maintenance, or DSOM©, and its use by the New York Housing Authority to reduce energy costs and maximize efficiency of its facilities is an example of how work for commercial customers supports DOE's missions.

3.7 Infrastructure Needed to Support Energy Research

New facilities and investment in infrastructure are needed to support PNNL's energy-related research, particularly to support research related to bio-based products, emissions and fuel efficiency, and nuclear S&T.

Bio-Based Processes and Products

We are teaming with WSU Tri-Cities to construct a Bioproducts, Sciences, and Engineering Laboratory. This facility will support rapid creation and deployment of new bio-based products that use agricultural byproducts and residues, supporting the regional agriculture economy and increasing the competitiveness of regional food processors while addressing national and regional energy needs (Module 3.1.3). This facility will consolidate our biomass research laboratories into a single space at approximately 60,000 to 70,000 square feet. Further, this modern laboratory will provide the ability to conduct research in both chemical and biological processes, supported by the best analytical and concentration and purification methods available. This showcase facility will support DOE research as well as draw industrial and academic users to collaborate with our scientists.

Energy

Nuclear S&T

Radiological and radiochemical facilities are essential to high-quality nuclear science and technology work. During this planning period we are readying our Radiochemistry Processing Laboratory for transfer to the site cleanup contractor, while continuing to use our unique capabilities to support national security, environmental management, and energy clients. Key to maintaining core radiological capabilities are the planned radioscience and global security buildings.

Increasing Fuel Efficiency and Reducing Emissions in Vehicles

In support of EERE and its goals to maximize fuel efficiency while minimizing harmful emissions from vehicles, we plan to consolidate its resources related to emissions research. By centralizing this equipment, including a new diesel engine for testing, we can enhance our ability to understand emissions behavior and explore technologies that reduce emissions without negatively affecting fuel efficiency.

Catalysis Research

To maximize the impact of the EMSL as a user facility and to further develop environmental, chemical, and physical sciences in support of DOE's mission, we are exploring the feasibility of building a catalyst research facility (Module 3.1.2). This laboratory would build on existing strengths in oxide chemistry, computational chemistry, computational fluid dynamics, chemical physics, nanoscience, and heterogeneous catalysis to focus on discovery in catalysis and chemical transitions and expediting catalyst development and testing. While the primary intent of the facility is support research for BES, we also would leverage these capabilities to support the missions of EERE and FE.

Fuel Cells and High-Temperature Electrochemistry

Ongoing and expanding efforts to explore solid oxide fuel cells (Module 3.3.1), hydrogen energy systems (Module 3.1.1), and high-temperature electrochemistry (Module 3.1), will require a greater need for laboratory space with ventilated hoods. Because much of this work involves hydrogen and other flammable gases, these hoods are needed to conduct our materials development and cell testing. Larger, walk-in hoods, such as the two added in the HiTEC Laboratory in FY 2003, allow more experiments to be conducted at the same time and more effective use of the equipment. In addition, limits on how much hydrogen can be stored inside a building led to the purchase of a hydrogen generator in FY 2003. As our programs continue to expand, there may a need for additional hydrogen generators.

The Bioproducts, Sciences, and Engineering Laboratory has received support from the state of Washington; the facility design costs are included in the state's FY 2004 budget.