Science & Technology HIGHLIGHTS

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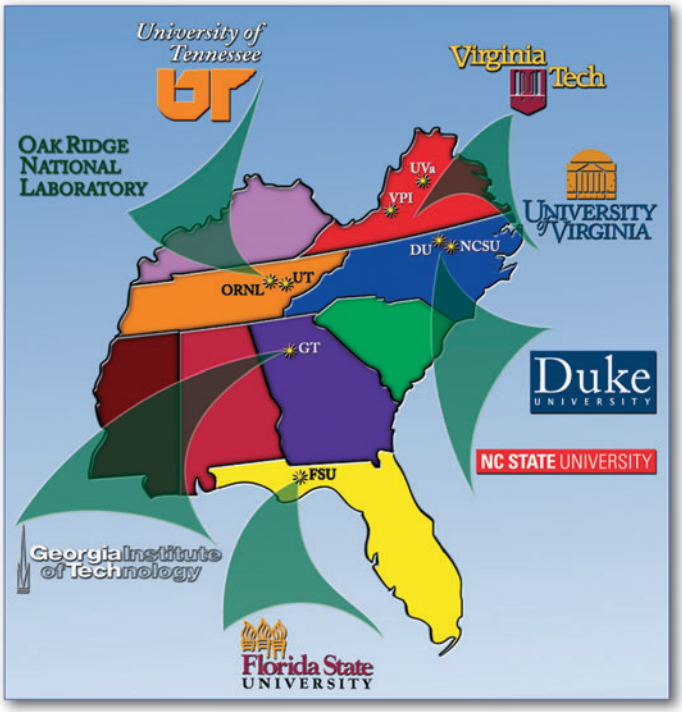
ORNL / University Partnerships Offer "Reciprocal Value"

As many of the articles in this newsletter illustrate, university partnerships have spawned numerous technical and commercial successes for ORNL's Energy Efficiency and Renewable Energy Program. As co-inventors, collaborators, and colleagues, university and laboratory researchers have benefited from each other's unique strengths and capabilities.

Core University Partners. As part of its management strategy for ORNL, UT-Battelle has established a novel "core university" collaboration among ORNL and six leading universities in the Southeast: Duke, Florida State, Georgia Tech, North Carolina State, Virginia, and Virginia Tech. As a partner in the management contract for ORNL, the University of Tennessee also has a close working relationship with the Laboratory. This innovative alliance enables the Lab and the universities to use one another's strengths to advance their scientific missions, employing the concept of "reciprocal value."



For ORNL, the core universities have committed to using their talent and resources whenever possible to further ORNL's R&D. The ability to access faculty expertise from the universities augments ORNL's resources and enables it to pursue research opportunities it otherwise might have to forego, said Lee Riedinger, ORNL's Deputy Director for Science and Technology. "The universities often have expertise we don't. Funding is sometimes unpredictable—the Lab must be able to move immediately to seize opportunities. Access to the universities' expertise helps us be nimble and responsive." The universities also operate as emissaries between ORNL and the larger academic community; each university chose an area of emphasis for itself and seeks to be a leader in helping other institutions of higher learning understand what ORNL has to offer.

For the core universities, the association with ORNL brings expanded opportunities for research and for recruiting experienced researchers as faculty members. Having access to ORNL's unique research facilities and equipment offers the universities a competitive edge in attracting faculty, students, and funding. Another advantage is the opportunity for university scientists to participate in interdisciplinary research at ORNL. Cross-disciplinary projects are taken for granted at the Lab, but they are less common in the academic world.

The core universities play a major role in charting the scientific direction of the Laboratory. They hold six of the nine places on the Science and Technology Committee of the UT-Battelle Board of Governors that reviews ORNL's science programs at the highest level. They also have representatives on the committee that selects ORNL Corporate Fellows.

One promising initiative ORNL and the core universities have undertaken is joint faculty appointments. These appointments allow faculty members from the University of Tennessee, core universities, and other universities with ties to ORNL to teach at the college campus for one semester a year and conduct research at the Laboratory for the rest of the year. ORNL and the academic institution each contribute about half of the cost of the position. By the end of 2003, ORNL and the core universities expect to have eight joint appointments in place: two each from Virginia and Georgia Tech and four from North Carolina State.

HBCUs and MEIs. ORNL is committed to developing science and technology collaborations with Historically Black Colleges and Universities (HBCUs) and Minority Education Institutions (MEIs). For the past three summers, ORNL has sponsored a research grant program in which faculty from HBCUs conduct research at ORNL during the summer months. The goal is to build research bridges between ORNL and HBCUs. Participation in this program has grown from 16 faculty in the summer of 2001, to 17 in 2002 and 19 in 2003. We look forward to expanding this program further; it is an effective way of building staff/faculty relationships that are essential for R&D partnerships and student flow.

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Calculating Costs and Benefits of Federal Energy Programs

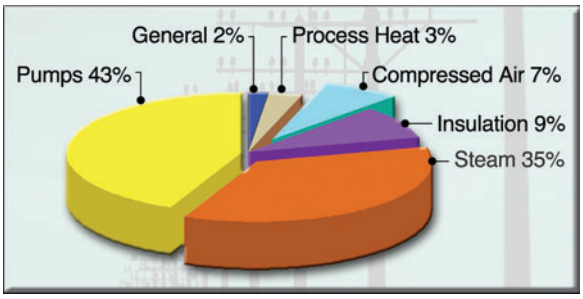
Since passage of the Government Performance and Results Act of 1993, agencies have had a heightened interest in measuring the impacts of their programs. ORNL has had a strong role in supporting DOE EE/RE in providing credible third-party estimates of the costs and benefits associated with government-funded energy programs over the years. Those efforts have also advanced the science of measuring benefits and costs.

How Much Energy Do Best Practices Save?

DOE's Best Practices program works to improve industrial practices for using and managing energy. It helps clients target energy-wasting equipment and processes (e.g., pumps, process heating, steam, compressed air, motors, and insulation) using a variety of tools and methods. These include Internet-based resources such as software, publications, and technical training and assistance.

ORNL has conducted a preliminary evaluation of energy savings resulting from Best Practices activities. The project estimated total savings for 2001 (including savings from plantwide assessments) at 0.078 quad, about 0.21% of the total energy used by U.S. industry, representing a roughly estimated cost savings of $468 million.

The ORNL team used previous evaluations, where possible, to estimate energy savings from particular activities. These included evaluation reports on the Motor Challenge and the Compressed Air Challenge Programs, the Industrial Assessment Center (IAC) database, and ORNL's previous evaluation experience with the IAC. Other sources of primary information included Collaborative Targeted Assessment energy savings estimates, estimated and reported savings from plantwide assessments, the Best Practices Activity Report, case studies results, and the Clearinghouse database. These sources offered energy savings estimates per application and evaluations of the likelihood that efficiency measures would be implemented.



Pumps and steam systems have the greatest potential for estimated savings.

Technologies with the largest estimated savings were pumping and steam systems. The assessment method generating the most savings was software, followed by software training and Collaborative Targeted Assessments.

Energy savings may be overestimated because of inaccurate estimates of the number of tools provided or the number actually used. However, overestimates probably are outweighed by underestimates due to excluding the continuing use of tools and more-efficient equipment over future years.

Next steps in improving these preliminary estimates include better tracking of the distribution of Best Practices tools and services and detailed information on the uses of software tools.

ORNL, with assistance from the University of Tennessee, is currently concluding an evaluation of 2002 Best Practices. For more information on the program, see www.doe.gov/bestpractices.

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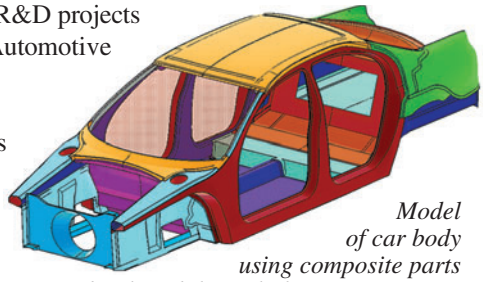
Sponsor: DOE/EERE Industrial Technologies

Calculating Federal Research Funding Payoffs

A University of Tennessee/ORNL benefit–cost analysis of three automotive R&D projects supported by the Automotive Lightweighting Materials (ALM) Program of DOE's FreedomCAR and Vehicle Technologies suggests that federal investment in the research has paid off handsomely. A ratio of 1 is considered marginal but acceptable; the lowest benefit–cost ratio among the three ORNL projects was 63.



Model of car body using composite parts developed through the ALM program.

UT's Energy, Environment, and Resources Center and Department of Urban and Regional Planning and ORNL conducted the evaluation of the three ALM projects. The first was to improve the design and production of lightweight, high-strength cast-aluminum components. The second sought to reduce the tooling time for dies for cast aluminum components from a year to less than 12 weeks, and the third was to improve the durability of composite materials via design criteria and performance standards.

To evaluate the projects, the research team used three standard assessment methods:

- a benefit-cost analysis (e.g., the increased market penetration made possible by federal support, compared with its absence)
- National Research Council indicators (e.g., publications and presentations produced)
- Qualitative assessments based on the participants' judgment of project benefits

The overwhelming majority of project participants (including auto industry and other private-sector representatives) said the projects had achieved their technical objectives and that their companies would not have pursued the R&D on untried technologies without federal participation. Three auto industry respondents said their companies have begun using the design protocols produced by the lightweight composites project.

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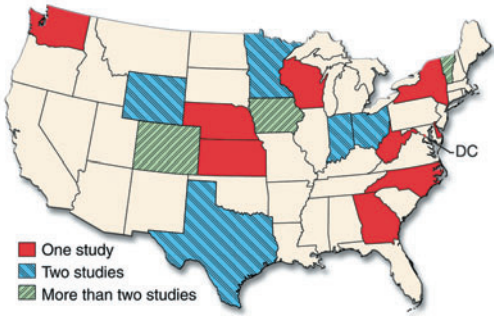
Measuring Weatherization Effectiveness

The National Weatherization Assistance Program weatherizes homes for low-income residents to increase their energy efficiency and lower utility bills. From 1990 until the present, ORNL has performed ongoing evaluations of the Program's performance. The first and most comprehensive study, which examined energy savings in a national sample of several thousand structures weatherized in 1989, was completed in 1993. Since then, three updates to that study's findings have been conducted using the technique of metaevaluation (metaevaluation involves collecting and integrating findings of a number of studies on the same issue).



Findings from 37 state-level evaluations provided the data for the metaevaluation.

The data points for the metaevaluation of Weatherization Assistance Program performance were the findings from 37 state-

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Developing a Framework for R&D Decisions

After a National Research Council committee developed a framework for estimating the benefits of DOE's energy efficiency and fossil energy programs, ORNL organized a conference to refine the framework for possible DOE use. Conference participants issued a final synthesis report on their work in the spring of 2003.

The following matrix for defining R&D benefits emerged from the conference:

	Past	Future	
	Realized	Projected base case	Option cases
Economic			
Environmental			
Security			
Knowledge			

The rows of the matrix reflect DOE's mission of undertaking energy R&D that improves the public good—economic well-being, the environment, energy security, and knowledge. The columns represent timeframes and levels of uncertainty about the benefits.

The final synthesis report is available at the conference web site: http://www.esd.ornl.gov/benefits_conference/

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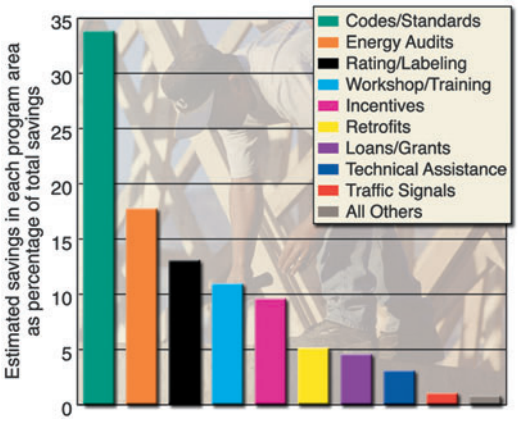
Sponsors: DOE/EERE Planning, Budget Formulation, and Analysis; DOE Offices of Fossil Energy; Science; and Nuclear Energy, Science and Technology

Savings Achieved by State Energy Program

There is no road map for evaluating the benefits of a program involving hundreds of separate activities that are implemented differently in every one of 50 states. Faced with the task of quantifying the effects of DOE's State Energy Program (SEP), staff at ORNL developed a set of "enumeration indicators" to describe key activities within 20 distinct program areas. In 14 of those areas, sufficient data were available from recent evaluations of state energy efficiency and renewable energy programs to estimate average energy savings per activity. To calculate energy savings, those per-unit estimates were multiplied by state-provided data on the number of activities undertaken. The energy-savings values were the basis for calculating cost savings and emissions reductions.

All states, territories, and the District of Columbia were contacted in late 2001 and asked to provide counts of their SEP activities for the most recent program year. Twenty states, representing nearly 50% of the U.S. population, responded by August 2002.



Five key program areas accounted for 85% of the savings resulting from State Energy Program activities.

About 85% of the energy savings achieved by these states occurred in the top five program areas: Codes and Standards, Energy Audits, Rating and Labeling, Workshops and Training, and Incentives. Most remaining energy savings came from Retrofits, Loans and Grants, and Technical Assistance. In all 14 program areas with quantifiable outcomes, annual energy savings were estimated at nearly 19 trillion source BTUs, and cost savings were almost $120 million. Carbon emissions were reduced by nearly 330,000 metric tons annually.

The estimated reductions for the 20 states can be extrapolated to the whole nation based on the proportion of total SEP funding represented by the states that provided data. Estimated annual energy and cost savings for the nation totaled over 41 trillion source BTUs and $256 million, respectively. Carbon emissions were reduced by nearly 720,000 metric tons; emissions reductions for SO_2 and NO_x were also substantial. These savings and emissions reductions indicate that the SEP is operating effectively and is having a substantial positive impact on the nation's energy situation.

The SEP report is available at http://www.naseo.org/about/SEP_study.pdf.

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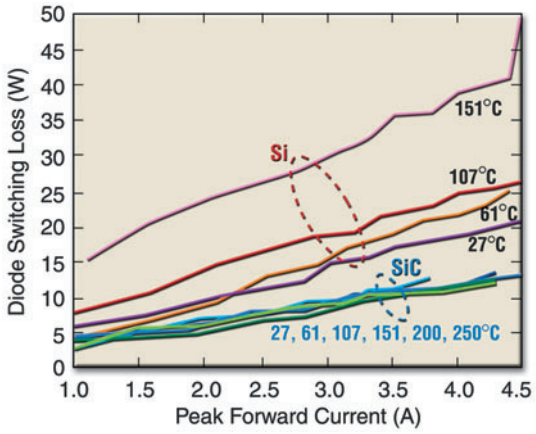
Sponsor: DOE/EERE Weatherization and Intergovernmental Grants

Developing SiC Semiconductors for Power Electronics

The performance of power electronics converters is increasingly important as more of the electricity we use is processed by converters in motor drives, dc-dc systems, distributed energy resource interfaces, flexible ac transmission systems, and high-voltage dc systems. Already, many converter applications use silicon-based devices connected in series to regulate voltages in the tens and hundreds of kV. In the near future, converters will process gigawatts of power between generation and end use, making highly efficient converters and systems essential.

ORNL's Power Electronics and Electric Machinery Research Center (PEEMRC) is focusing on developing silicon carbide (SiC) power electronics technologies that are more efficient and durable, as well as significantly smaller and lighter, than conventional devices based on silicon.



Switching losses of an SiC Schottky diode do not change with temperature.

Most current commercial power electronics devices are silicon-based, and their performance is approaching the theoretical limits of silicon's material properties. The emergence of wide-bandgap semiconductor materials such as SiC, gallium arsenide, gallium nitride, and diamond will substantially improve the blocking voltages, efficiency, and reliability of converter systems and reduce their thermal requirements.

Because SiC technology is the most mature among the wide-bandgap semiconductors, it is PEEMRC's main focus. Researchers affiliated with ORNL and the University of Tennessee are investigating the system-level benefits of SiC power devices for hybrid electric vehicles (HEVs). They have derived theoretical SiC metal-oxide semiconductor field effect transistor (MOSFET) computer models and experimental SiC Schottky diode models and integrated them into a model for an HEV traction drive.

The HEV model showed that using SiC instead of silicon power devices would result in system-level benefits such as reduced losses, increased efficiency, and reduced size and volume. When SiC power devices replace Si devices in a traction drive, its efficiency increases by 10%, and the required size of the heat sink for the drive is reduced by two-thirds.

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Sponsor: DOE/EERE FreedomCAR and Vehicle Technologies

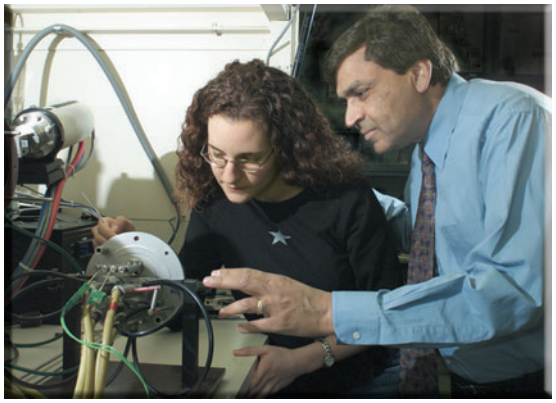
Universities Utilize HTML's Unique Capabilities

The High Temperature Materials Laboratory (HTML) at ORNL provides unique instrumentation for advanced materials characterization (www.ms.ornl.gov/htmlhome/). Since opening in 1987, HTML has worked with more 260 universities and 350 U.S. companies. Two recent HTML collaborations with universities are highlighted in the following paragraphs.

Scientists from Vanderbilt University are working at the Mechanical Characterization and Analysis User Center to evaluate the mechanical properties of polymer matrix composites reinforced with graphitic carbon nanofibers (GCNFs). GCNFs may be useful in fabricating stronger composite materials for lighter, more fuel-efficient vehicles. Preliminary research has focused on using Raman spectroscopy to determine tensile properties, fracture toughness, and local stresses. Testing at HTML found that tensile strength is inversely proportional and ductility is directly proportional to temperature. Fractographic analysis of the test specimens showed that unequal distribution of nanotubes can result in strength-limiting flaws.

Researchers from the University of Nevada–Reno used HTML's Diffraction User Center to study the metastable (not highly stable) alloy Zr_2Fe_3. These intermetallic phases have important applications for the absorption of hydrogen; however, phase equilibria under different atmospheres have not been fully evaluated and understood. X-ray diffraction (XRD) studies were done using HTML's controlled-atmosphere, high-temperature X-ray diffractometer, which enabled comparative studies under nitrogen, hydrogen, and inert atmospheres.

The results showed that if Zr_2Fe_3 absorbs hydrogen at a low temperature to form Zr_2FeH_x and later releases it at a high temperature, although the Zr_2Fe phase may not be regenerated, other equilibrium phases may form depending on the composition of the atmosphere. Such in situ XRD studies in inert, oxidizing, and H_2 atmospheres may be valuable for studying lightweight hydrogen storage materials. The ability to run these materials through several hydriding–dehydriding cycles while observing the lattice expansion and phase fractions is particularly important.



Professor Dhanesh Chandra and Jennifer Smith from the University of Nevada-Reno using the HTML's high temperature X-ray diffractometer.

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Sponsor: DOE/EERE FreedomCAR and Vehicle Technologies

Fuel Economy Web Site Tops the Charts

The web site www.fueleconomy.gov developed by ORNL and the University of Tennessee has become a popular and useful Internet destination for automotive consumers. It is continually improved and updated to promote informed vehicle purchasing decisions. Consumers can search the web site for specific vehicles by make and model, view side-by-side comparisons of up to four vehicles at once, and use the annual fuel cost calculator to estimate cost savings with a more fuel-efficient vehicle. The site also provides data on gas mileage and greenhouse gas emissions, air pollution ratings, and safety information for new and used cars and trucks.

Focusing on customer needs has earned the guide 120 Internet site awards. The launch of the 2003 edition produced the web site's busiest day ever with more than 27,000 user sessions. The number of visitors to the site has nearly doubled every year since its debut in 1999; more than 1 million users accessed the site in 2002.

On the day the 2003 edition was released, 42 web sites had articles pertaining to fuel economy on their homepages and referenced www.fueleconomy.gov. These web sites included front-page articles on Yahoo, MSNBC, ABC News, Canadian Driver, and EPA News.

The web site www.fueleconomy.gov provides users with information on vehicle fuel economy, air pollution ratings, and safety.

ORNL also produces the *Fuel Economy Guide*, a print version of the same kinds of information found on the web site. ORNL took over publication of the *Guide* and the web site in 2000. The 21-page booklet had long been provided to automobile dealers; ORNL began sending it also to public libraries and credit unions throughout the country to help consumers make buying decisions.

ORNL has steadily expanded the web site and made it more sophisticated, flexible, and user-friendly. The site averaged 987 visits per day in 2000 and now averages more than 9000 user sessions daily.

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Sponsor: DOE/EERE Weatherization and Intergovernmental Grants

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The researchers calculated ratios for three cases, a low, moderate, and high level representing the range of the monetary value of the impacts reported in the literature today. For the moderate case, the benefit-cost ratio was 69 for the casting project, 211 for rapid tooling, and 63 for composite materials. The three projects also resulted in 111 presentations and 64 publications over 4 years.

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Sponsor: DOE Automotive Lightweighting Materials Program, Office of FreedomCAR and Vehicle Technologies

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level evaluations of weatherization efforts completed between 1993 and 2002. ORNL contacted each state program office in 1996, 1998, and 2002 to locate and obtain all available state-level evaluations of the Program's energy savings. In addition, ORNL completed several evaluations with state partners to obtain data points from underrepresented geographic regions. In all of the metaevaluations, models were developed only for gas-heated homes, because this was the only fuel for which there were enough state studies to allow a reasonably accurate analysis.

In the 2003 metaevaluation (available at http://weatherization.ornl.gov/pdf/CON_488.pdf), a simple regression analysis was performed using energy savings as the dependent variable and pre-weatherization energy consumption as the sole independent variable. Like many previous studies, this metaevaluation found a strong positive relationship between pre-weatherization energy consumption and weatherization-induced savings: 67% of the variance in energy savings is explained by pre-weatherization energy consumption, and there is a probability of only 1 in 10,000 that the correlation could have occurred by chance. The actual savings usually fall close to the prediction line. The accuracy of this model suggests it is a good tool for estimating Weatherization Assistance Program energy savings.

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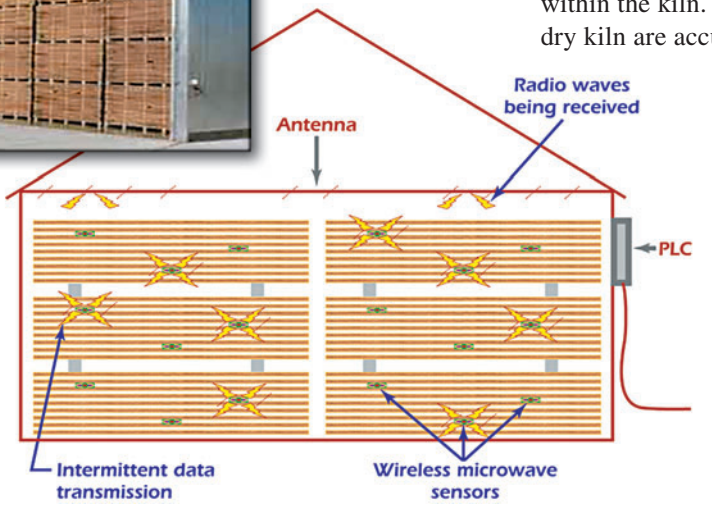
Sponsor: DOE/EERE Weatherization and Intergovernmental Grants

Sensors Save Energy, Prevent Damage in Lumber Drying

ORNL and University of Tennessee researchers are collaborating to develop novel sensor technology for energy-efficient kiln drying of lumber. The team goal is to obtain data from strategically located sensors in the lumber load that can be used to reduce drying times and energy usage by 20% or more and at the same time guard against damage due to faulty drying.

Energy is the largest cost in drying, and drying uses the most energy of any step in the entire production process for many wood materials, from harvesting to finished products.

Small enough to be placed throughout a lumber pack in the kiln, the new real-time moisture content (MC) sensors can communicate with existing control systems used in kilns. They will provide better information about the average moisture and the moisture distribution within the kiln. Most existing sensors for a dry kiln are accurate only over the range of 25% to 6% MC; the ORNL microwave sensor system, tested at two different frequency ranges on oak and poplar, has shown a linear response from 80% down to 5% MC. This increased knowledge, particularly at the critical region of 35% to 25% MC, will allow kiln operators to greatly



The schematic (bottom) illustrates how sensors collect moisture data on lumber drying in a kiln (left).

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Simulated Flooding Puts Building Materials to the Test

Flooding causes more damage to buildings in the United States than any other natural cause—an estimated $30 billion in property damages since 1990. To reduce losses, builders and owners need to know which building materials and techniques resist flood damage and can be more readily restored after flooding.

To identify water-resistant materials and methods, ORNL and Tuskegee University building scientists are flooding and then testing simulated residential structures. ORNL will use the results to develop recommendations for improving resistance to flood damage in residential building envelopes.

Two 8×8 ft structures, one slab-on-grade module and one with a crawlspace, were built for each series of tests that simulate real-world residential materials and systems, flood conditions, and drying conditions. The modules were placed in outdoor basins in Tuskegee, Alabama, that were filled with water from an agricultural lake to 2 ft above floor level. They were submerged for 3 days, drained, and allowed to dry for 28 days.

The "houses" were tested for physical degradation and damage from water and biological agents such as mold and mildew. (The tests addressed only water damage, not structural damage resulting from debris or moving water.) The ease of cleaning and restoring the various types of materials was then evaluated.

Testing observations and evaluations found

- Drywall that was able to dry fairly quickly could be sanitized, repaired at the joints, and repainted to pre-flood appearance.
- The use of sprayed polyurethane foam (SPUF) in wall cavities facilitated restoration because, unlike batt insulation, SPUF did not hold water and allowed walls to dry faster.
- Sealed concrete floors and ceramic floor and wall tile held up well; but carpeting had to be removed, and simulated wood flooring warped and was marginally salvageable.
- Vinyl and fiber cement siding performed better than plywood and hardboard siding.

A third set of tests evaluated the potential to dry–floodproof a home (keep the interior dry during a flood). While these attempts were unsuccessful, several other types of materials for siding, walls, and floors performed well. Future modules will test the impact of more-contaminated floodwater on various construction methods.

Flooded module (above) and drywall with mold and mildew growth after being under water.

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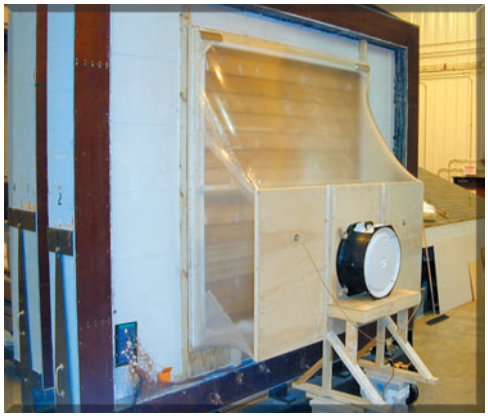
Sponsor: DOE/EERE Building Technologies, Federal Emergency Management Agency, Department of Housing and Urban Development

On-line Air Leakage Calculator for Building Designers

Air leakage accounts for 30–40% of the energy used in homes and more in commercial buildings. It depends on many factors, including the building envelope, air-sealing techniques, building geometry, and construction quality. Analyzing air leakage sources in building energy simulations, an essential step in designing low-energy buildings, requires a detailed database of the air leakage characteristics of building envelope components.

Such a database is not currently available, but researchers at ORNL's Buildings Technology Center are constructing a Web-based air leakage calculator to be available by late 2003 for use in building energy calculations. It will be similar in form to ORNL's widely used Whole Wall Thermal Performance Calculator (www.ornl.gov/roofs+walls/calculators/wholewall/index.html).

As part of the effort, ORNL formulated new field and laboratory procedures to test airtightness in building components.



This blower door setup allows ORNL researchers to test the airtightness of an experimental clear wall section.

Data from tests conducted using the procedures will populate the database.

The full field procedure consists of blower door tests and infrared monitoring of an entire house. During each test, a different set of building interfaces and details (potential air paths) is sealed. The results help identify infiltration areas and evaluate component airtightness. This procedure was used to analyze several low-energy houses built in Lenoir City, Tennessee. Another procedure uses blower-door tests on a one-room test hut. During 2002, tests were conducted to evaluate the airtightness of several structural insulated panel technologies. A third procedure, based on ASTM standard E 283 on determining air leakage, was used to characterize infiltration in wall intersections with ceilings, foundations, and windows. These tests compared and evaluated air sealing techniques and materials.

Available data on air infiltration are based mostly on limited testing of whole wood-frame buildings. Energy effects of advanced framing techniques, envelope materials, envelope components, and air-sealing technologies remain uncertain because reliable data on their effectiveness are lacking. ORNL's air leakage calculator will be the only source of experimental data for detailed building envelope air leakage characteristics in North America. ORNL researchers hope the calculator will be incorporated into the interactive materials database for Energy Plus, a whole-building simulation tool being developed by DOE (see http://www.eere.energy.gov/buildings/energyplus/).

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Sponsor: DOE/EERE Building Technologies

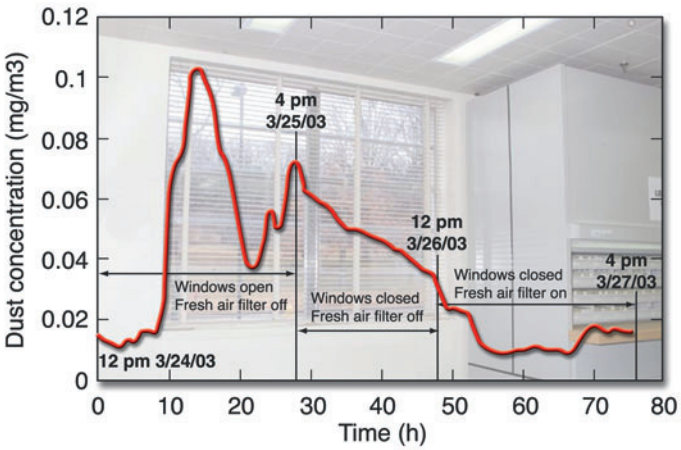
Healthier Housing for Low-Income Households

Airborne contaminants inside dwellings often cause or aggravate respiratory ailments such as asthma and other illnesses. Because they are more likely to live in poorly built and maintained dwellings, low-income families are particularly vulnerable to "sick house syndrome." To address this problem, building scientists at ORNL and Tuskegee University have designed and constructed an energy-efficient "healthy house" suitable for low-income households.

The prototype dwelling was designed to investigate several residential indoor air quality (IAQ) issues that can affect occupants' health: excessive moisture that promotes mold and fungus growth and dust mites; chemicals escaping from building materials (volatile organic compounds); and ventilation problems that reduce oxygen, increase carbon dioxide, and introduce other particulate allergens.

The healthy house is designed to be affordable for a small family in which the provider earns the minimum wage. The 768-ft^2 model is located at Tuskegee's experimental farm in Tuskegee, Alabama. It has two bedrooms, one bath, a kitchen, a living room, and small utility areas. In addition to a standard heat pump for heating and cooling, the house contains a HEPA-filtered air system that provides fresh air to the well-sealed house.

Air quality and energy monitoring devices are installed that enable Tuskegee to measure and assess the IAQ and energy efficiency of the dwelling under various conditions. Sensors monitor indoor and outdoor temperatures and relative humidity; energy consumption; ventilation fan operating times; and CO_2, volatile organic compounds, and particulates inside the house.



This chart of dust concentrations shows the effectiveness of the air filtering system in eliminating airborne contaminants in the healthy house.

Sensor readings have established baseline parameters for IAQ indicators such as particulates, including pollen. Determining the impact of these kinds of air parameters is an important part of being able to improve IAQ and ultimately the health of a building's occupants.

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Sponsor: DOE/EERE Building Technologies

Improving Ventilation and Air Quality in School Classrooms

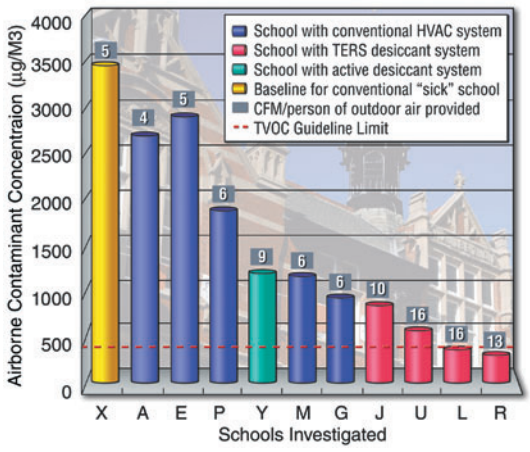
An ORNL study demonstrates the effectiveness of desiccant dehumidification in maintaining adequate ventilation and acceptable indoor air quality (IAQ) in school classrooms. It suggests active humidity control may be especially useful in schools, given their high occupant densities and heightened sensitivities to allergens and asthma.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 62-1999 recommends a minimum ventilation rate of 15 cfm/person in classrooms. That ventilation level challenges conventional heating, ventilation, and air-conditioning (HVAC) systems because dehumidification is the largest part of the ventilation air treatment load. Conventional systems dehumidify air only as they cool it. When the outside air is humid but not particularly hot, cooling units will not operate long enough to dehumidity incoming air effectively. Humid air feels uncomfortable and encourages the growth of mold and other pathogens in classrooms. Desiccant-assisted HVAC systems, however, dehumidify independently of cooling.

Continuous ventilation and active humidity control can provide better air quality in classrooms.

ORNL worked with Georgia Tech, Georgia State University, and SEMCO, Inc., to assess the effects of continuous ventilation and humidity control in schools. The project also provided baseline IAQ data for developing recommendations and HVAC system designs to improve the indoor environment in schools.

Ten schools were studied, ranging from 1 to 8 years old. None had a history of IAQ complaints. Schools in the same geographic/climate region were paired, one with a conventional HVAC system and one with a desiccant-assisted system. Each school was equipped with continuous CO_2, temperature, and humidity monitors; and on-site sampling was conducted at each school at least four times over a 2-year period.



Admitting more fresh, dry air to classrooms reduces levels of airborne contaminants.

Study results show that continuous ventilation and active humidity control significantly benefitted classroom IAQ. Supplying 15 cfm/person of fresh, dry air to classrooms measurably reduced levels of airborne contaminants. In schools with conventional HVAC systems, humidity rose to unacceptable levels if 15 cfm/person of fresh air was supplied. CO_2 and indoor contaminant levels rose if ventilation was decreased to control humidity.

Systems with continuous ventilation and active humidity control also were more energy-efficient at higher temperatures than the conventional systems because they could maintain comfortable conditions.

More information on IAQ and humidity control R&D at ORNL is available at www.ornl.gov/ORNL/BTC/desiccant.html.

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Sponsor: DOE/EERE Distributed Energy

Taking Active Humidity Control to the Streets

To spread the word about the benefits of desiccant dehumification, ORNL has launched a mobile exhibit that allows visitors to experience active humidity control first-hand while they are browsing information about the technology. The Desiccant Humidity Control (DHC) Van, housed aboard a tractor-trailer rig, incorporates

The Desiccant Humidity Control Van touts the benefits of desiccant dehumidification.

- informative displays on the technology and benefits of desiccant systems
- two environmental chambers that allow visitors to compare the comfort provided, at different levels of humidity and temperature, by desiccant-based and conventional cooling systems
- guided tours led by desiccant technology and humidity control experts who can answer questions about moisture management in buildings and indoor air quality

The DHC Van is available for tours at gatherings of interested parties such as heating, ventilation, and air-conditioning

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(HVAC) industry trade associations, professional societies, and utility-related groups. The unique communication and technology transfer effort promotes markets for desiccant-based air-conditioning products by demonstrating their features and allowing HVAC system designers and potential customers to experience for themselves the comfort of the technology.

The traveling show is part of a move by DOE to accelerate the deployment of desiccant technology as a means of saving energy, improving indoor air quality, and reducing moisture damage in buildings due to excessive humidity. One of ORNL's tasks is to demonstrate the performance of packaged HVAC systems that include desiccant humidity control equipment. Another is to help small desiccant system makers work with large HVAC companies who are beginning to build and market such packaged systems. Using the trailer to introduce and demonstrate desiccant technology to industry groups aids both of those efforts.

During its first year of operation, the DHC Van has been displayed at the 25th World Energy Congress, Atlanta Gas Company, the Business Energy Solutions Conference and Expo, and the American Society for Healthcare Engineering International Conference and Exhibition on Health Facility Planning, Design, and Construction.

Information about the schedule for the van and about hosting tours of the DHC Van is available at http://www.ornl.gov/desiccantvan/hosting.htm.

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Sponsor: DOE/EERE Distributed Energy

ORNL and TVA Team Up to Test New Transmission Lines

Like the heating coils on an electric stove, power transmission lines heat up when high currents pass through them. Utilities must restrict the amount of current they send through power lines to avoid the problems that high temperatures cause, such as excessive sagging. As demands on the U.S. power grid increase, utilities are looking to new types of transmission line conductors to help solve capacity problems and avoid blackouts such as the August 14, 2003, system collapse that caused 50 million Americans to lose electrical power.

To aid in the search for better conductors, ORNL has worked with the Tennessee Valley Authority (TVA) utility to design and assemble a transmission line section that will be studied at a new facility at ORNL called Powerline Conductor Accelerated Testing (PCAT). PCAT is one of several new and planned facilities that comprise ORNL's National Transmission Technology Research Center (NTTRC).

"PCAT is designed to operate conductors at up to 300° Celsius, exceeding maximum-rated temperatures for most powerline conductors," said Mike Ingram of TVA's Energy Research and Technology Applications. "This will let us evaluate new technologies and materials for transmission lines."

The low-voltage, high-current ORNL testing facility makes it possible to evaluate advanced technologies realistically under a wide range of conditions without jeopardizing the reliability of an operating power grid. It will operate at up to 5000 amps of direct current and up to 400 volts. A 2400-foot length of conductor is installed on two 600-foot spans that make up three powerline structures.

James Glotfelty of DOE (right) tours the PCAT facility with TVA and ORNL officials during its recent dedication.

Monitors installed on the powerline structures measure conductor temperatures and ambient temperatures, wind speed and direction, and incident solar radiation. PCAT can simulate aging of lines by repeatedly heating the conductors and then allowing them to cool to the ambient temperature. This allows researchers to evaluate how a conductor design is likely to perform through its life cycle.

"We have to raise the awareness of the cost of doing nothing, letting our transmission grid continue down the path of lower power quality and poor reliability," James Glotfelty, senior policy adviser to Energy Secretary Spencer Abraham, said at the recent NTTRC dedication.

Reliability problems with the power transmission system cost an estimated $100 billion annually, and power quality problems cost another $25 billion, Glotfelty said. "The cost of doing nothing means higher electricity costs," with consumers footing the bill.

A new powerline conductor made by 3M has been installed at PCAT for testing. It consists of ceramic fibers embedded in aluminum and surrounded by temperature-resistant aluminum-zirconium wires.

A ribbon-cutting for the PCAT facility was conducted on March 25, 2003.

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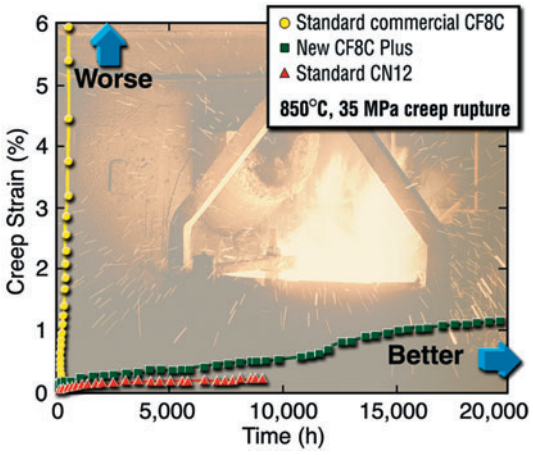
Sponsor: DOE Office of Electric Transmission and Distribution, TVA

Hot New Steel Promising for High-Temperature Applications

Researchers at ORNL and Caterpillar have developed a new stainless steel that is stronger and tougher at both high and low temperatures than standard steels without costing more. Not only the steel itself but also the method of producing it, termed "engineered microstructures," are being hailed as revolutionary.



CF8C-Plus stainless steel outperforms other steels at both high and low temperatures.

The new technology recently received an R&D 100 award from *R&D Magazine*, recognizing it as one of the most significant scientific achievements of the year.

Development of the new steel, CF8C-Plus, was driven by the need for engine components that can perform reliably at temperatures of up to 800–850°C. Higher engine operating temperatures result in greater fuel efficiency and lower emissions.

It was made by making changes to the composition of CF8C, a common stainless steel. Careful additions of manganese and nitrogen to CF8C, adjustment of the other alloy components, and microscale and nanoscale manipulation of the grain structure produced the improvements. Ordinarily, there is a tradeoff between strength and ductility (flexibility)—the stronger the steel, the more brittle and prone to cracking. CF8C-Plus contains scattered particles of niobium carbide (NbC), which adds strength at high temperatures. However, the alloy is engineered so that the NbC nano-particles form only after the material is exposed to high temperatures during use. It is less strong, and thus more ductile, during the casting phase and gains the strength it needs after it is put into use. Consequently, it is easier to cast than most competing steels and needs no post-casting heat treatment or processing.

Phil Maziasz of ORNL (right) discusses CF8C-Plus stainless steel with DOE Secretary Spencer Abraham (left) and Senator Lamar Alexander.

Whereas CF8C cast steel is reliable at temperatures up to 650°C, CF8C-Plus is strong, ductile, and resistant to fatigue and creep behavior at up to 850°C. Few steel alloys are usable at temperatures higher than 850°C, and those are more difficult to cast and more susceptible to fatigue and creep at high temperatures. CFC8-Plus also has shown outstanding resistance to oxidation.

Immediate applications planned for CF8C-Plus are exhaust components, such as manifolds and turbocharger housings, for heavy-duty diesel engines. It is expected to be directly applicable for many other uses, including marine diesel engines, industrial gas turbines, microturbines, gasoline auto engines, natural gas reciprocating engines, and large, advanced land-based gas or steam turbines.

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Sponsor:DOE/EERE FreedomCAR and Vehicle Technologies and Distributed Energy

IACs Promote Careers in Energy

For the past several years, ORNL has coordinated many student activities associated with DOE's Industrial Assessment Centers (IACs) that go beyond the conduct of assessments. These activities are meant to encourage professional development and help the students transition into energy-related careers. Activities include an annual student meeting in Washington, D.C., a student/alumni web site (www.iacforum.org), interaction with professional organizations, gaining recognition from state engineering licensure boards for IAC experience, and IAC student certificates. Currently about 50% of the IAC students graduate into careers related to energy; over time, the savings impact of the program will significantly increase as this "army of energy engineers" hits the marketplace.

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increase the drying rate without risking excessive degradation of the lumber.

ORNL has designed and built a prototype low-power sensor to go into the kiln that provides a microwave probing signal, measures the returning signal, and stores the results in a memory chip on the card. It also logs temperature and provides a communication interface.

The last phase of the energy-efficiency project will be to integrate existing ORNL wireless spread-spectrum transmission technology with the sensors developed in this project. The final product is envisioned as a small, completely potted (encased in epoxy) instrument that will survive kiln conditions and will take and record MC and broadcast data at set intervals. The unit will "sleep" when not actually taking or broadcasting data, to conserve battery life.

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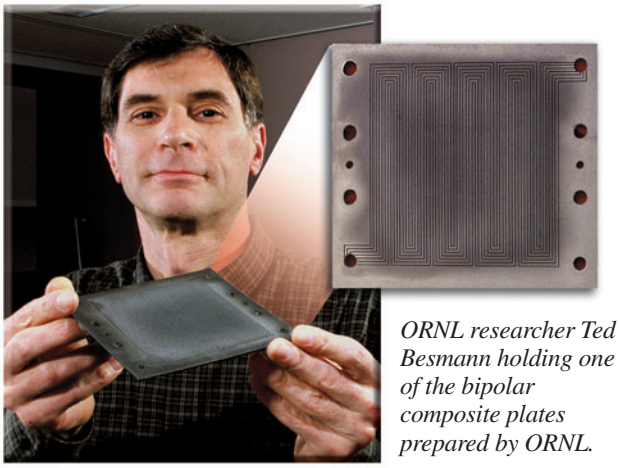
Sponsor: DOE/EERE Industrial Technologies

Composite Plates Reduce Cost and Weight of Fuel Cells

ORNL has developed a carbon composite bipolar plate for fuel cell vehicles that will be indispensable in reducing their cost and weight. A low-cost plate molding process and a novel coating method enable it to meet technical targets while reducing production costs.

Bipolar plates are a key component of proton exchange membrane (PEM) fuel cells. Developing suitable plate materials is technically challenging because the plate must maintain high electrical conductivity in both oxidizing and reducing environments, be chemically compatible with the aqueous environment



ORNL researcher Ted Besmann holding one of the bipolar composite plates prepared by ORNL.

and the polymer electrolyte, have mechanical integrity, and separate and distribute reactant gas streams. Plates for vehicles must be made of inexpensive material and amenable to high-volume, low-cost manufacturing. DOE's cost target is $10/kW, or approximately $1–2 per plate (0.5-$m^2$ in area).

High-density graphite has been used for bipolar plates; however, material and machining costs for graphite are prohibitive. ORNL developed a low-cost slurry-molding process to produce a carbon-fiber plate preform, into which flow fields are embossed rather than machined. Chemical vapor infiltration is used to coat the plate with a layer of carbon, making it hermetic and highly conductive. Testing of ORNL's bipolar plate has yielded promising results, and cost estimates suggest it could be produced for less than $2 per plate. ORNL is working with Porvair Fuel Cell Technology, which has licensed the technology, to scale up production to the pilot plant level and provide significant numbers of plates for evaluation.

The goal for an automotive PEM fuel cell is a 40-kW system that costs less than $2,000 and weighs less than 133 kg, vs the current $12,000 and 200 kg. The carbon composite bipolar plates will reduce the fuel cell cost by about $5500 and its weight by 40 kg. In addition to powering vehicles, PEM fuel cells may be useful as stationary power generators. For more information, see www.ornl.gov/EERE/hydrogen.htm

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Sponsor: DOE/EERE Hydrogen, Fuel Cells, and Infrastructure Technologies

UniVane: A Superior Respiratory System for Fuel Cells

Because they are fueled by gases (hydrogen and oxygen), fuel cells must breathe to work. Like animals, they need "lungs" that are powerful, efficient, and adaptable to different levels of effort.

The UniVane® compressor, a collaborative effort between DynEco and ORNL, is designed to meet the unique gas-flow needs of proton exchange membrane (PEM) fuel cells. It delivers air and hydrogen at the specific pressures and volumes needed for PEM operation; it can introduce water vapor into the fuel to keep the membranes moist (a necessity for PEMs); and it does not use lubricants, which would contaminate the fuel cell stack.

Conventional compressors and fans do not work well as fuel cell components; compressors require lubrication, and fans cannot sustain adequate pressure and flow. UniVane operates at the particular pressure range fuel cells require, which is somewhat low for pumps and high for fans. Pressure range is important because fuel cell size and cost can be reduced in proportion to the pressure at which the stack operates. Tests at ORNL showed the UniVane's volumetric efficiency is over 90% at 5 psig and near 100% at 3 psig, and the overall efficiency is 68%. This is two to three times the efficiency of conventional compressors, a key factor because the fuel system operates on power from the fuel cell.

The UniVane compressor is a better set of "lungs" for PEM fuel cells.

The UniVane reduces friction by several means to avoid using lubricants: controlled clearance sealing, antifriction bearings, low-friction materials, air-bearing effects, and large ports. It has several attributes vital to fuel cells:

- simple, compact design
- only flat and round parts, which are easy to make
- no rubbing parts
- large inlet and outlet flow areas
- completely oil-free operation
- highly efficient compression
- vibrationless mechanism
- water injection capability

The UniVane's capability to inject water along with the fuel eliminates the need for a separate humidifier. DynEco estimates this feature alone could reduce the initial cost of a 5-kWe fuel cell by $500 to $1000.

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Sponsor: DOE/EERE Hydrogen, Fuel Cells, and Infrastructure Technologies

News Briefs

Clean Energy Dedication

David Garman, Assistant Secretary for the Office of Energy Efficiency and Renewable Energy, and several congressional representatives were at ORNL on August 5 for a combined groundbreaking ceremony for the Advanced Materials Characterization Laboratory, dedication of the test machine for automotive crashworthiness (TMAC) at the National Transportation Research Center, and startup of the first consumer-owned solar power system to supply power to the Tennessee Valley Authority power system. The solar system is installed on a highly energy-efficient Habitat for Humanity dwelling built under the direction of DOE's Building America Project.

David Garman and the TMAC

National Academies honor Greene

ORNL Corporate Fellow David Greene has received a lifetime appointment as a national associate of the National Academies. The appointment recognizes Greene's "extraordinary work and service to the National Academies in advising the government and the public on matters of science, technology, and health."

Tech Transfer Awards

An ORNL team developing a carbon composite bipolar plate for fuel cells won a 2003 Excellence in Technology Tranfer Award from the Federal Laboratory Consortium for Technology Transfer. Team members are Ted Besmann, Tim Burchell, John Henry, and James Klett. (See article on p. 11.)

CF8C-Plus Wins R&D 100 Award

ORNL's CF8C-Plus cast stainless steel, developed by Phil Maziasz and Robert Swindeman, received an R&D 100 Award from *R&D Magazine*, recognizing it as one of 2003's most important scientific achievements. (See article on p. 10.)

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