Science & Technology HIGHLIGHTS

Published by Oak Ridge National Laboratory's EERE and OE Programs No. 2 2005

EERE Partners with States to Encourage Energy Efficiency

A key mission of ORNL's EERE Program is research leading to the development and deployment of sustainable energy resources. Collaboration with states provides effective approaches to accelerating the use of sustainable energy technologies nationally. ORNL's work with states is based on four major initiatives that engage states in encouraging energy-efficient practices:

The **State Partnerships Program** awards ORNL research and technical assistance support to states through project solicitations. The principal partners targeted through this process are the National Association of State Energy Officials and the Association of State Energy Research and Technology Transfer Institutions. Since the program began in 1996, ORNL EERE has completed projects with energy offices in 39 states. Recent projects include these:

- ORNL researchers analyzed energy efficiency alternatives in Iowa and determined that a combination of market-based programs and standards targeting the residential and commercial sectors offers the greatest payback for state funding.
- Researchers with ORNL and the University of Tennessee, the U.S. Environmental Protection Agency, and New Jersey are analyzing emissions and fuel use in idling long-haul trucks to help state offices support development of technologies to reduce emissions and fuel waste.

- Seattle is plagued by failures of recently constructed buildings due to moisture damage. The city and Washington State University partnered with ORNL to determine the causes of the premature deterioration and develop building envelope designs and control strategies for energy efficiency and moisture control.

The **Technical Assistance Project** assists states through a collaborative effort among three DOE national labs—ORNL, National Renewable Energy Laboratory, and Lawrence Berkeley National Laboratory. It supports short-term technical assistance for initiatives involving ratepayer-funded utility efficiency/renewable programs, renewable/efficiency portfolio standards, use of clean energy technologies to address air emissions, and use of renewable energy on state and local public lands. Examples of recent projects supported through ORNL are

- Development of emissions metrics associated with state implementation plans for improving air quality in Tennessee.
- Recommendations for an energy-efficiency portfolio standard for New Jersey.
- Assessment of the soil composition of state land for growing biomass fuels in Florida.

ORNL is collaborating with the **Education and Research Consortium of the Western Carolinas** (ERCWC) to translate technology concepts into marketable products to reduce energy usage and costs and to support economic development and education in rural West Carolina. Five projects are currently under way, involving ERCWC and other regional partners:

- Development of climate-based software to support EERE applications for local, state, and regional use.
- Manufacture and testing of an energy-efficient dual-service water heating appliance prototype.
- Creation of a Western Carolina Office of Technology Transfer, supported by EERE technologies transferred from ORNL and other organizations.
- Support for development of a Western Carolina industrial assessment center at a community college.
- Creation of a user-friendly exhibit in North Carolina's new arboretum to educate the public on energy-efficient practices.

Through its work with the **Weatherization** and **State Energy Programs** (SEPs), ORNL helps states improve the efficiency and effectiveness of their low-income residential weatherization programs. ORNL's assistance includes the ongoing development and improvement of the National Energy Audit Tool and the Manufactured Housing Energy Audit Tool, the development of metrics and project management expertise for the SEPs, and the development of expertise in energy industry economics.

The ORNL-EERE Program's success at achieving energy sustainability and security for the nation depends greatly on maintaining and developing fully engaged partnerships and collaborations with all major players in the marketplace.

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ORNL/TVA Partnership Promotes Performance,

ORNL, the nation's largest energy lab, is partnering with the Tennessee Valley Authority, the nation's largest public power producer, to promote operational excellence, accelerate the deployment of new technologies, and support economic development for the utility industry and the nation.

Promoting operational excellence

TVA and ORNL are collaborating on more than a dozen advanced technologies for the benefit of Tennessee Valley residents and businesses.

Like much of the nation, TVA periodically experiences high levels of congestion on its transmission grid. One promising approach to expanding TVA's grid capacity is to replace some of its power lines in bottleneck areas with cables that can transport greater volumes of electricity. ORNL's transmission research expertise prompted a collaboration that in 2003 culminated in the creation of ORNL's Powerline Conductor Accelerated Testing facility (www.ornl.gov/sci/oetd/facilities/htm). With DOE funding, TVA helped design the facility and has coordinated with ORNL to develop protocols for testing advanced conductor designs.

DOE has approved the construction of the Transmission Power Electronics Test facility (TPET) on the ORNL campus. This facility will accelerate full-field demonstration and deployment of new power electronic technologies and help gain utility acceptance of these devices. It will provide a full-power (high-voltage and high-current), in-the-grid environment for sorting out prototype issues and ensuring successful field demonstration. It also offers a full range of operating condition extremes to build utility confidence and ensure adequate design. TVA will provide staff support and in-kind services to support TPET construction at the new ORNL substation.

Power cables being tested at ORNL's PCAT facility on Bethel Valley Road.

ORNL has also worked with TVA to develop and test a hydropower draft tube turbulence measurement system using acoustic Doppler velocimeter probes. The equipment has been field-tested at TVA's Melton Hill Dam.

Accelerating technology deployment

The deployment of new technologies is accelerated by translating TVA's knowledge of Tennessee Valley customers' needs and values into advanced energy technologies developed by ORNL and made available through TVA programs.

In response to homeowner complaints about the cold air that blows from heat pumps when their coils frost, ORNL developed the "frostless heat pump." The invention employs an accumulator to maintain warm temperatures, reduce the "cold-blow" effect, and reduce energy use, thereby lowering utility bills. With assistance from TVA, a regional manufacturer for the frostless heat pump accumulator is being located.

TVA and ORNL are working with industry to introduce frostless heat pumps to the market.

TVA's Green Power Switch program was the first statewide program in the Southeast to promote power produced by sunlight, wind, and landfill gas. ORNL supported the establishment of this program by signing up to be the first industrial customer to buy the renewable energy.

In another highly successful collaboration, ORNL and TVA introduced the concept of "zero-energy buildings" (ZEBs) to the Tennessee Valley. With support from DOE, product manufacturers, and a local Habitat for Humanity affiliate, four near-ZEB homes have been constructed that showcase advanced solar photovoltaic (PV) energy systems and energy-efficient materials and equipment. The owners of these homes were the first residential customers to sell power back to the TVA grid through TVA's Generation Partners program. This project has been recognized in national publications such as *Mother Earth News*, *ASHRAE Journal*, and *Automated Builder* and was introduced to President

Technology, and Economic Development

George W. Bush as a DOE national lab achievement (www.ornl.gov/sci/btc/news.htm).

Supporting economic and community development

ORNL's technology transfer mission is the perfect complement to TVA's economic and community development missions. TVA/ORNL cooperation offers significant economic and community development potential in support of businesses and communities in the region.

The automotive supply industry is one of the largest and fastest-growing segments of Tennessee's economy. TVA is conducting an industry-wide survey of automotive manufacturers to assess their technology needs and is certifying megasites that can support automotive manufacturing plants.

ORNL and TVA are also working together to provide the region with the high-speed connectivity required to grow high-tech businesses and conduct world-class research. TVA and ORNL have established a fiber optic network infrastructure to connect universities in the Tennessee Valley with ORNL's supercomputer center and other major national research and education networks. This capability is expected to foster education and technology development, encourage new business ventures, and help develop the overall economy of the Tennessee Valley.

The $55 million renovation of the 50-year-old Oak Ridge High School, located about 10 miles from ORNL, is an opportunity for TVA and ORNL to contribute to the community by facilitating the use of green technologies such as ground-source heat pumps to provide energy-efficient heating and cooling. TVA drilled the initial test holes to determine the conductivity of the ground; the tests resulted in the decision to use this technology in the final design.

Leveraging R&D resources

TVA and ORNL have coupled their staff expertise and resources to achieve research goals that are important to both organizations, including the sharing of research facilities and co-funding of research, development, and deployment.

Jeff Christian of ORNL briefs President George W. Bush and Energy Secretary Samuel W. Bodman on zero-energy houses.

TVA and DOE funded ORNL to quantify the indirect benefits that PV panels can provide to buildings as the result of increased rooftop shading. At the completion of this first-of-a-kind experiment and analysis, which used the unique test capabilities of ORNL's Buildings Technology Center, the panels were moved to a school in nearby Campbell County, TN, where they are used in the educational curriculum.

Solar tracker installed at the American Museum of Science and Energy.

In another project, TVA funded ORNL to demonstrate the operation of hybrid solar lighting at the American Museum of Science and Energy in Oak Ridge. A third-generation collector and tracking system was installed that uses a lightweight, low-cost plastic mirror. In a previous project, TVA and DOE co-funded the design and development of hybrid solar luminaires that are a key feature of the technology (www.ornl.gov/sci/hybridlighting).

TVA and ORNL also have teamed to examine high-efficiency building materials. Several years ago, TVA built a house near Chattanooga with a wall system built of blocks of autoclaved cellular concrete (ACC). ACC blocks contain 70% fly ash, a waste produced by TVA's coal-burning power plants, and weigh up to 80% less than ordinary concrete blocks. In a side-by-side experiment, ORNL tested the same wall system at the Buildings Technology Center to determine its energy benefits as a building material. ACC blocks are the product of a Tennessee Valley company and recycle fly ash from TVA's Bull Run Steam Plant in Oak Ridge.

Preserving environmental quality in East Tennessee

TVA and ORNL are working to preserve the unique environmental quality of the Tennessee Valley region through research in air quality modeling, sensor technologies, and carbon sequestration options.

TVA commissioned ORNL in 2002 to conduct a preliminary assessment of the potential to sequester carbon dioxide (CO_2) in deep underground geologic formations near TVA's 11 coal-fired plants. The purpose of the study was to determine if there were suitable formations—un-mineable coal seams, depleted oil and natural gas reserves, and/or saline aquifers—below or near each plant. ORNL staff reviewed existing geologic and well data and, based on that information, rated each plant as to the potential to store CO_2 in one or more formations. If TVA is required to reduce or sequester CO_2 emissions in the future, then this and other information will be used to select coal-fired plants for detailed assessment.

ORNL and TVA continue to assess areas of mutual interest in developing and deploying advanced technologies and leveraging capabilities to lead the nation to further energy security and efficiency, economic and community development, and environmental quality.

Plant-Wide Energy Assessments Reap Big Savings for Industry

Paper mills like this one in Arkansas are among the nation's largest energy users.

DOE EERE's Industrial Technologies Program (ITP) works with the U.S. industries that are the largest energy consumers to improve their energy efficiency by conducting plant-wide energy assessments. Companies that have taken advantage of the program so far represent the chemical, aluminum, glass, steel, mining, petroleum, and forest products industries.

ORNL's Industrial Energy Efficiency group administers the plant-wide assessment program for DOE. ITP co-sponsors the assessments based on a competitive process through its Best-Practices Program. The purpose of the assessments is to examine plant utility and process operations to identify opportunities to improve energy efficiency, productivity, and global competitiveness while reducing waste and environmental emissions. To date, results have been reported from assessments conducted at 37 facilities.

The combined annual potential cost savings identified through assessments at the 37 facilities are nearly $200 million. Potential annual electric and thermal energy savings are estimated at 452 GWh and almost 0.02 quads (quadrillion Btu), respectively. The average investment payback period is expected to be less than two years, less than a year in some cases. Significant non-energy benefits to be gained through project implementation include increased productivity, reduced environmental impact, and decreased maintenance requirements.

ORNL tracks and reports data on energy and cost savings for plants participating in plant-wide assessments. Information on implemented and replicated projects and their associated savings is also collected. For more information, see www.oit.doe.gov/bestpractices/assessments.shtml.

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Sponsor: DOE/EERE Industrial Technologies Program

METALDYNE EYES SAVINGS OPPORTUNITIES

Metaldyne, Inc., recently completed a plantwide assessment at its forging facility in Royal Oak, Michigan. A team of energy and manufacturing process experts identified 21 recommendations during the study. If all the assessment recommendations were implemented, the team estimated that total annual electricity savings would be about 11.5 GWh and the Royal Oak plant could save more than $12.6 million annually in overall plant energy and operating costs. The cost of implementing the projects would be approximately $6.5 million.

Headquartered in the metropolitan Detroit area, Metaldyne operates 45 facilities throughout the world and has more than 7,500 employees worldwide. The Royal Oak plant manufactures forged parts in several ways. Hot-forging processes produce high-volume products that include transmission and transfer case components and wheel-end components. The plant has the world's largest concentration of Hatebur hot-forging machines, which forge concentric parts from carbon and alloy steels. It is also capable of warm-forging parts that require greater precision than can be achieved with hot forging. In addition, Metaldyne is one of the world's largest cold forging companies. Heat treating of parts has traditionally been outsourced.

The assessment addressed opportunities to increase energy efficiency, reduce waste and pollutants, and increase productivity by evaluating demand-side energy management, best practices, opportunities for implementing emerging technologies, and potential supply-side changes. The assessment concentrated on the plant's large energy-using systems and equipment. The large equipment included the solid-state induction heaters for the Hatebur hot-forging machines; the warm-forging press; the hot-forging vertical press; the Wagner hot ring rollers; electric motors; material handling equipment; heating, ventilation, and air-conditioning; and lighting. Product inventory and the potential for reducing or eliminating defects were also examined. Processes were examined for potential lean manufacturing/best practices improvements (lean manufacturing seeks to reduce waste throughout the production process). The assessment team also identified some emerging technologies that could improve manufacturing efficiency.

Taking Wireless Network Testing to the Extremes

ORNL's Extreme Measurement Communications Center (EMC2) is working with U.S. companies and government agencies to advance the deployment of wireless technology under extreme conditions typical of industrial settings. EMC2 formalizes procedures for testing industrial wireless networks to quantify latency, throughput, security, and fault-tolerance. It is being developed both as a user facility and as a provider of on-site testing using portable analysis equipment.

ORNL is part of a community developing wireless network standards that support the introduction of suites of robust wireless products from many vendors that operate successfully in interference-prone and physically harsh manufacturing environments.

The Center provides modeling, simulation, and characterization support for industrial wireless networks. Its resources include parallel computing resources and measurement equipment for high-performance wireless and wired network characterization. Broadband radio frequency recording and playback instruments can simulate and generate characteristic waveforms for laboratory study of a device's behavior in harsh industrial-type conditions.

One of EMC2's current projects is exhaustive modeling and simulation to develop fault-tolerant communication infrastructure for the electric grid of the future. It also is supporting DOE Sensors and Automation wireless projects being carried out by Honeywell, Eaton, and GE that use characterizations of standard industrial environments to fine-tune their individual implementations of wireless sensor networks. EMC2 will evaluate protoype networks supplied by each project. In addition, it is helping private companies and the National Nuclear Security Administration evaluate environments in which they wish to deploy wireless devices and candidate technologies for particular applications.

EMC2 director Wayne Manges presented a class in implementing wireless technology at a recent ISA symposium, and GE and Honeywell representatives made presentations on their EMC2 projects.

The Wireless Industrial Networking Alliance has designated EMC2 as the product testing and characterization center for its member companies. For more information, see www.ornl.gov/sci/emc2/.

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Sponsor: DOE/EERE Industrial Technologies Program

Identifying Cleaner Fuels for Marine Diesel Engines

When the U.S. Navy needed to evaluate its options for cleaning up emissions from its diesel-powered ships, it turned to ORNL for help. Researchers at ORNL's Fuels, Engines, and Emissions Research Center (www.ntrc.gov/labs/feerc.shtml) conducted a joint Navy investigation to elucidate the performance of a two-stroke marine engine operating on five types of fuels and determine their effect on engine performance and emissions of particulate matter (PM) and nitrogen oxides (NO_X).

Marine diesels produce 14% and 16% of global NO_X and sulfur oxides emissions, respectively. And since shipping traffic is concentrated along coasts and at ports—cities such as Los Angeles, San Francisco, Houston, and Boston—it is a large source of PM and NO_X pollution in these regions. The Environmental Protection Agency, MARPOL (the international body that regulates shipping), and the California Air Resources Board are now regulating emissions from marine sources, and complying with regulations will require low-sulfur fuel and emission control.

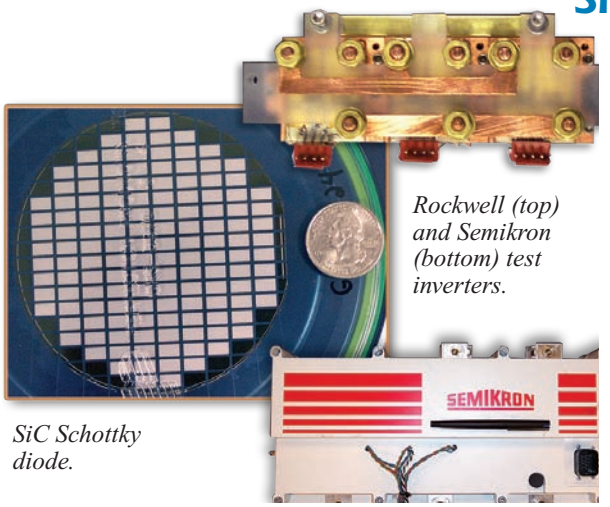
The ORNL team set out to evaluate the effect of several fuel types on the engine performance and emissions of an unmodified two-stroke, DDC 12V-71 engine located at the Navy's engine test facility at Philadelphia. The fuels evaluated were F-76, JP-5, ultra-low-sulfur, a Fischer-Tropsch–derived fuel (low-emission synthetic diesel), and a biodiesel blend containing 20% vegetable oil and 80% ultra-low-sulfur fuel.

ORNL provided an analytical bench and an FTIR spectrometer to collect PM emissions and to speciate the exhaust gas chemistry. The engine was operated according to the ISO 8178 D2 and E5 test cycles. For each mode, engine efficiency and regulated emissions were measured and FTIR analysis conducted for unregulated compounds.

River barges use marine diesel engines.

continued on p.12

SiC Inverters for Hybrid Electric Vehicles



Rockwell (top) and Semikron (bottom) test inverters.

SiC Schottky diode.

Silicon (Si) has been the most widely used semiconducting material for decades. However, as new electronics push the limits of Si's material properties, other semiconductors are emerging that will improve the blocking voltages, efficiency, and reliability of power electronics systems and reduce their thermal requirements.

The most developed new semiconductor is silicon carbide (SiC). Therefore, researchers at ORNL's Power Electronics and Electrical Machinery Research Center (www.ornl.gov/sci/engineering_science_technology/peemrc) are focusing on the benefits of SiC power devices for use in hybrid electric vehicles (HEVs).

Recently, ORNL collaborated with several companies to build two different inverters using SiC devices. In one project, the Si pn diodes in Semikron's 55-kW automotive inverter were replaced with CREE SiC Schottky diodes, keeping the Si main switches intact to form an Si–SiC hybrid inverter. The materials were mixed because while some SiC Schottky diodes are commercially available, SiC switch technology is less advanced. Therefore, an interim step before all-SiC inverters are abundant might be Si–SiC hybrids for HEVs. SiC Schottky diodes are more efficient than Si diodes and have negligible reverse recovery currents (these cause losses and increase electromagnetic interference). Extensive dynamometer and inductive load testing of this hybrid inverter showed a decrease of up to 35% in inverter losses. It is expected that when SiC main switches also replace their Si counterparts, inverter losses will be reduced by up to 65%.

For the second inverter, ORNL teamed with Rockwell Scientific to build a 7.5-kW all-SiC inverter using SiC switches and SiC Schottky diodes. (A low power level was used because SiC switch technology is not mature enough for high-power inverters.) Extensive testing will be conducted to show the system-level impact of both SiC power switches and SiC Schottky diodes and to predict what the impact would be for higher-power inverters for HEVs. If results are as promising as for the Si–SiC hybrid inverter, plans are to build a 55-kW all-SiC inverter.

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Sponsor: DOE/EERE FreedomCAR and Vehicle Technologies Program

Pew Report Looks toward More Climate-Friendly Buildings

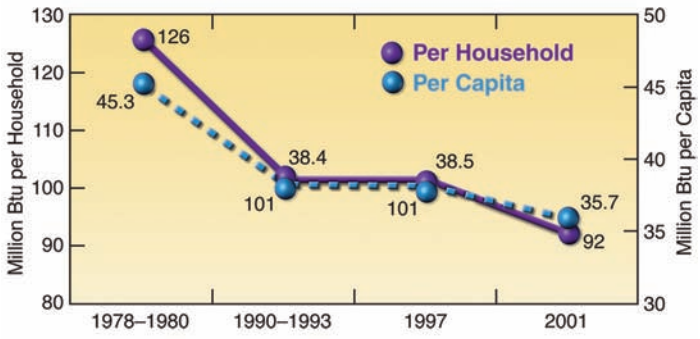
The Pew Center for Climate Change recently released the report *Towards A Climate-Friendly Built Environment*, authored for Pew by Marilyn Brown, Frank Southworth, and Therese Stovall of ORNL. The report concludes that dramatic environmental improvements in the building sector are possible over the next few decades if changes are adopted soon and pursued over the long term.

It presents a far-reaching review of opportunities to conserve energy and reduce greenhouse gas (GHG) emissions through improved building designs. Numerous energy-efficient technologies from DOE and the national laboratories are included in the review.

Following the release, at the Pew Center's request, Brown presented the report's findings to the National Press Club and Congressional staff.

The breadth of coverage distinguishes this report from previous energy-efficiency technology reviews. For instance, it characterizes the life-cycle energy impacts of alternative building materials and equipment. It examines how siting buildings more efficiently within broader urban land-use arrangements would affect GHG emissions. Finally, it provides an overview of six GHGs linked to building, including, for example, methane from construction debris in landfills. These topics have received limited coverage in the energy and climate change literature.

The report finds that a portfolio of affordable technology and policy options exist to dramatically curb GHG emissions



Residential energy use per capita and per household have declined consistently since the 1970s.

from the buildings sector over the next 50 years. However, the lead time required to develop new technologies, deploy available ones, and turn over capital stock means policies need to be launched now to create the impetus for change. Efforts must be sustained over time to achieve the deep reductions required.

This report is part of Pew's Solutions series. The first sector report in the series, *Reducing Greenhouse Gas Emissions from U.S. Transportation*, was co-authored by David Greene of ORNL.

Both of these reports can be found at www. pewclimate.org/global-warming-in-depth/all_reports/.

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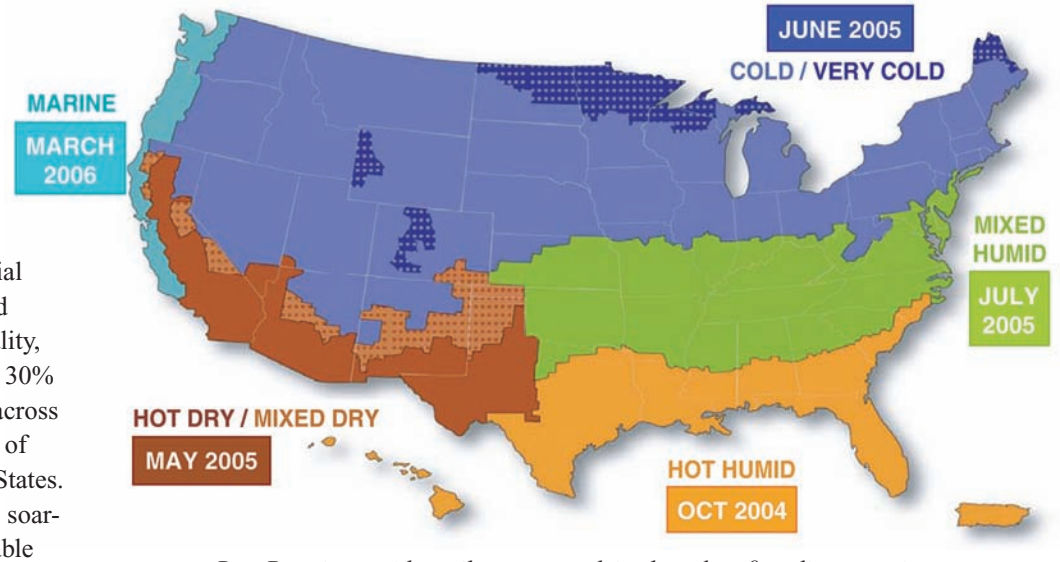
Climate-Specific Home Building Guides Provide Targeted Energy Tips

The Building America program at ORNL is working with Pacific Northwest National Laboratory to provide a climate-specific Best Practices Series promoting energy efficiency in residential housing.

These Best Practices residential building guides offer tips to targeted audiences on how to build high-quality, energy-efficient homes that achieve 30% energy savings in various climates across the country. Homes use nearly 21% of the total energy used in the United States. With energy consumption and costs soaring, efforts made to develop affordable energy-efficient solutions are expanding.



Best Practices guides tailor energy advice based on five climate regions.

Building technologies research and development conducted and sponsored through DOE's Building America program is aimed at improving the comfort and efficiency of American homes while reducing their demand for electricity. The development of this Best Practices series provides necessary resources for the building industry to implement the latest cutting-edge energy-saving technology and techniques. Energy-efficient building requires taking into account regional climate variables such as temperature, rainfall, humidity, wind patterns, and snow loads.

Five guides are planned for the series:

- Volume 1: Hot-Humid, released October 2004
- Volume 2: Hot Dry–Mixed Dry, released May 2005
- Volume 3: Cold–Severe Cold, released June 2005
- Volume 4: Mixed Humid, available September 2005
- Volume 5: Marine, available in early 2006

The fourth guide in the series, "Mixed Humid," addresses the challenge of maximizing energy efficiency while preserving the comfort of homes in mixed-humid climates, which include the East Tennessee region. A mixed-humid climate is characterized by more than 20 inches of rainfall per year, significant demands for both cooling and heating, and high humidity levels for much of the year. Equipped with this guide, builders and homeowners will be able to build high-quality, energy-efficient homes that can save 30% in space conditioning and water heating each year in this climate zone.

DOE's Building America Program is reengineering new and existing homes for energy efficiency, energy security, and affordability. For more details and to download the guides, see www.buildingamerica.gov.

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Sponsor: DOE/EERE Building Technologies Program

This house is part of a residential development in Pittsburgh in which all the houses are built to Building America standards.

S&T Highlights is a communication of Oak Ridge National Laboratory's *Energy Efficiency and Renewable Energy Program, and Electricity Delivery and Energy Reliability Program*

Websites: **www.ornl.gov/eere** and **www.ornl.gov/etd**
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Oak Ridge National Laboratory is operated by UT-Battelle for the U.S. Department of Energy under contract DE-AC05-00OR22725.

OAK RIDGE NATIONAL LABORATORY
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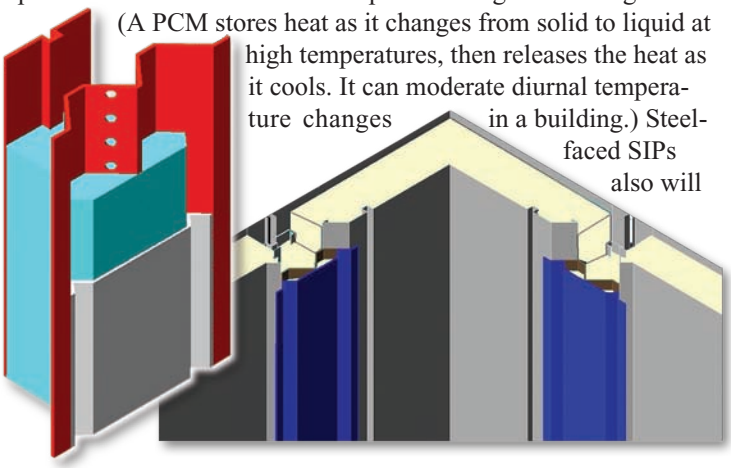
Steel-Clad SIPs Offer Superior Energy Efficiency and Durability

Researchers in ORNL's Buildings Technology Center are working with building industry partners to develop a steel-faced structural insulated panel (SIP) that is more resistant to damage from termites, fire, and wind and more energy-efficient than either conventional framing or SIPs currently being used in construction.

Existing SIPs consist of a core of foam insulation sheathed in oriented strand board. The new-generation SIPs are sheathed in thin steel instead of wood, have a core of closed-cell polyurethane foam, and incorporate a phase-change material (PCM) that provides thermal mass to reduce peak cooling and heating loads. (A PCM stores heat as it changes from solid to liquid at high temperatures, then releases the heat as it cools. It can moderate diurnal temperature changes in a building.) Steel-faced SIPs also will contain internal radiant barriers that reduce heat transfer. The R-value (insulating ability) of the panels is expected to be about R-20, compared with about R-9 for traditional framing.



The new SIPs will be faced with steel rather than wood and use phase-change material to control heat changes.

The wind tolerance of the steel-faced SIPs is substantially greater than that of traditional frame structures or existing SIPs, a characteristic that will make them attractive for building in hurricane-prone areas. In tests, a similar system has withstood winds of 150 mph. They also are noncombustible and impervious to termites and moisture. The interlocking panel connections will feature proprietary self-sealing seams that make the wall system virtually airtight and moisture-tight.

The panels can be dismantled and reassembled into different structures, an advantage that will enable economical reuse and minimize waste. Because of their resistance to fire, wind, moisture, and termite damage, they also are expected to reduce insurance costs.

The new panels are being developed through a partnership with SustainBuild, LLC. BASF and Advanced Fiber Technology are participating in development of the PCM inserts. The panels have been analyzed with extensive modeling and pilot testing. The technology is expected to be available to prospective licensees in 2005 or 2006.

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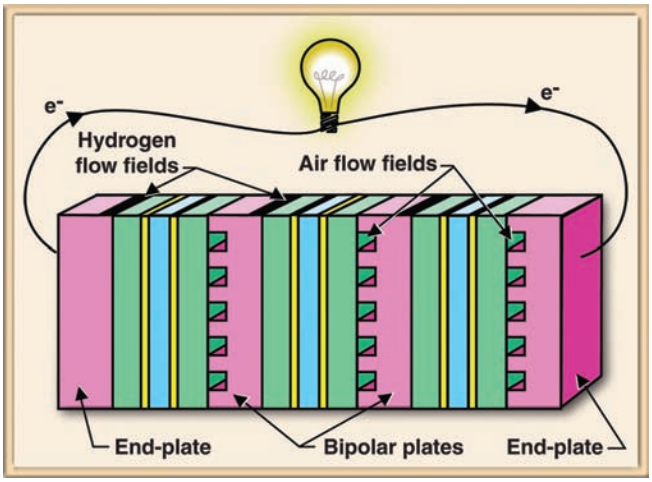
Sponsor: DOE/EERE Building Technologies Program, Oak Ridge National Laboratory, SustainBuild

New Steel Alloy Promising for Cost-Competitive Bipolar Plates

A proton exchange membrane fuel cell (PEMFC) relies on bipolar plates to connect individual fuel cells in a stack to achieve a useful voltage, and to distribute hydrogen and oxygen across the membrane electrode assembly. For PEMFCs to be competitive in cost and meet power density goals, less expensive and more mechanically robust plate materials are needed than the thick machined graphite currently used. Thin sheets of metals, although inexpensive and strong, have not been usable as bipolar plates because they are susceptible to corrosion, which can lead to high electrical resistance and/or contamination of the fuel cell membrane by dissolution of metal ion species. Deposited coatings on metal plates have not been effective, in part because they leave pin-hole defects that allow corrosion to develop.

ORNL is developing a chromium-bearing alloy that, when exposed to nitrogen, will form an electrically conductive, corrosion-resistant Cr-nitride surface layer that protects the underlying material. This approach has the potential to form continuous, defect-free surface layers on complex-shaped components.

Proof-of-principle research focused on nitridation of a model Ni-50Cr alloy. The nitridation surface treatment resulted



Bipolar plates channel air (oxygen) and hydrogen through the fuel cell assembly.

in a significant decrease in interfacial contact resistance (<20 $m\Omega/cm^2$ at loads of 100–150 N/cm^2), a key property for the interconnection function of the bipolar plate. During a 4100-h

continued on p.9

exposure in a hot, acidic environment simulating fuel cell operating conditions, the alloy exhibited excellent corrosion resistance, little metal ion dissolution, and negligible increase in contact resistance. Anode and cathode plates were manufactured from nitrided Ni-50Cr and successfully completed 1000 hours of fuel cell operation. The level of contamination was comparable to that for nonmetal bipolar plates, indicating that the Cr-nitride surface completely protected the plates' flow-field features.

This approach is inexpensive and can be implemented with existing industrial equipment. However, the model Ni-50Cr alloy tested is too expensive for many applications. ORNL is now focused on developing less expensive alloys with Fe/Ni bases or identifying suitable commercially available alloys that can form a similar protective surface. Test coupons and plates of nitrided alloys are being supplied to a number of fuel cell manufacturers and end-users for evaluation.

The nitride surface on these thin metal fuel cell plates protects them from corrosion.

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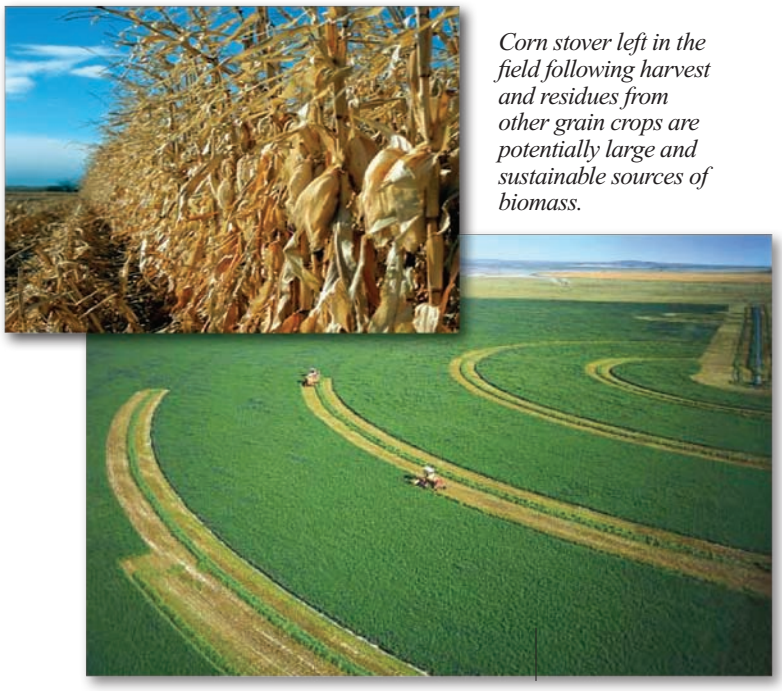
Sponsor: DOE/EERE Hydrogen, Fuel Cells, and Infrastructure Technologies Program

Biomass: A Billion Tons a Year of Renewable Fuel

Biomass recently surpassed hydropower as the largest domestic renewable energy source and now provides over 3% of the energy consumed in the United States. As the only current renewable source of liquid transportation fuel, it is particularly attractive because it can reduce oil imports—a pressing energy need. DOE and the U.S. Department of Agriculture (USDA) are committed to expanding the use of biomass to cut oil and gas imports; support the growth of agriculture, forestry, and rural economies; and foster a domestic biorefining industry making a variety of fuels, chemicals, and other products.



Corn stover left in the field following harvest and residues from other grain crops are potentially large and sustainable sources of biomass.

How large a role could biomass play? Could biorefining grow enough to have a major impact on energy supply and oil imports? Would its contribution be sufficient to justify infrastructure changes? Would enough biomass feedstock be available to warrant retooling some large, capital-equipment-intensive petroleum refineries to process biomass?

ORNL was asked to determine whether U.S. land resources can produce a sustainable biomass supply sufficient to displace 30% or more of the petroleum presently used. A joint advisory committee to DOE and USDA set 30% as the level of a major contribution to the U.S. energy supply. It would require around 1 billion dry tons of biomass feedstock per year.

The short answer to the questions is yes. ORNL found that just forest and agricultural land could produce more than 1.3 billion dry tons per year—enough to meet more than a third of current demand for transportation fuels. This potential is based on a more than seven-fold increase in biomass production. About 368 million dry tons of sustainably removable biomass could be produced on forest lands and 998 million dry tons on agricultural lands. In the time required to scale up to a large biorefinery industry, 1.3 billion dry tons of biomass could be produced with relatively modest changes in land use and agricultural and forestry practices.

The report is at http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf.

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Sponsor: DOE/EERE Biomass Program, U.S. Department of Agriculture

New ORNL Lab Is Testing the Use of Reactive Power

A Reactive Power Laboratory (RPL) being built at ORNL will test the use of reactive power from distributed energy (DE) resources (e.g., engine generators, fuel cells, and microturbines) to provide voltage regulation on electrical transmission and distribution networks.

Reactive power, measured in voltage ampere reactive (var), is produced when alternating current is out of phase with voltage because of inductive or capacitive loads. Imbalances in the supply and use of real and reactive power have caused electricity blackouts in North America in recent years.

Shawn Henry, a summer intern at ORNL, works in the Reactive Power Lab.

The RPL is developing testing scenarios for reactive power control and voltage regulation in the ORNL electrical distribution system. These will be used to develop design "rule of thumb" criteria for implementing reactive power–producing DE, and control methods to allow simple, reliable DE installation in a distribution system.

Some RPL goals over the next 2 years are these:

- Demonstrate that DE can provide reactive power locally for power factor correction and voltage regulation without extensive communication and control infrastructure and modification of the distribution system.
- Demonstrate that DE located in the distribution system can provide ancillary services (i.e., reducing var transport from central plants to loads) to the bulk power system.
- Demonstrate that DE can be an economical, cost-effective, practical method of voltage regulation.
- Determine the benefits, advantages, and disadvantages of synchronous-machine-based versus inverter-based DE resources (i.e., inverters may be able to compensate for all nonactive power—which includes reactive power, harmonics and unbalanced power—and inverters can inherently limit fault current).
- Investigate inverter design questions and propose goals for minimum continuous and short-term power factor, reasonable cost, dc-to-dc interface, and interface for conventional generators.

Major equipment in the Lab includes a 150-kW dc power supply, line inductors (2/4/6 mH), 480-V distribution power panels (1000 A, 600 A), motor starters, a 250-hp synchronous motor that will be used as a synchronous condenser, three sizes of 3-phase programmable inverters (75, 150, and 300 A), a 6.6-kW dc power supply for exciting the motor, two load banks (500 kW and 375 kVar), real-time power meters, real-time data control software and hardware, and eight mathematical simulation methods.

The real-time control software and mathematical software have been installed, and modeling of voltage regulation in the ORNL distribution system has begun, using a steady-state model developed by the ORNL facilities group. Later, a dynamic model will be built. The test plan involves collaboration with engineers for ORNL's distribution system to connect and operate the test equipment to inject reactive power at various points on the ORNL system. Shunt capacitor compensation will be relaxed at the ORNL substation, and motor starts and loads will be triggered by system engineers to provide a range of testing scenarios for the RPL.

Partners in the venture to date are Bowman Power, Capstone Turbines, Rolls Royce, Southern California Edison, Tennessee Valley Authority, and EPRI Solutions.

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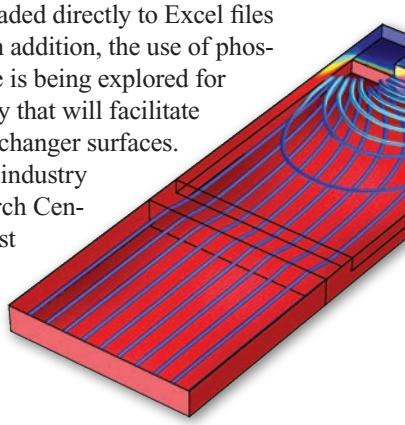
Sponsor: DOE/EERE Distributed Energy Program

Heat Transfer Lab: Designing Better Heat Exchangers

ORNL's Heat Transfer Test Laboratory (HTTL) is dedicated to reducing the size, weight, and cost of heat exchangers for thermally activated technologies. Its state-of-the-art instrumentation for noninvasive temperature measurement enables quicker setup and higher accuracy. High-resolution thermal imaging cameras produce temperature scans that can be downloaded directly to Excel files for fast data reduction and analysis. In addition, the use of phosphor paints excited with a light source is being explored for temperature measurement, a capability that will facilitate thermometry of hard-to-reach heat exchanger surfaces.

ORNL is working with several industry partners (United Technologies Research Center, Modine Mfg. Company, Southwest Gas Corporation, and DuPont) to design advanced heat exchangers and fluids for thermally activated technology applications. Collaborative research includes designing fluids for advanced cycles and improving heat exchanger materials and orientations.



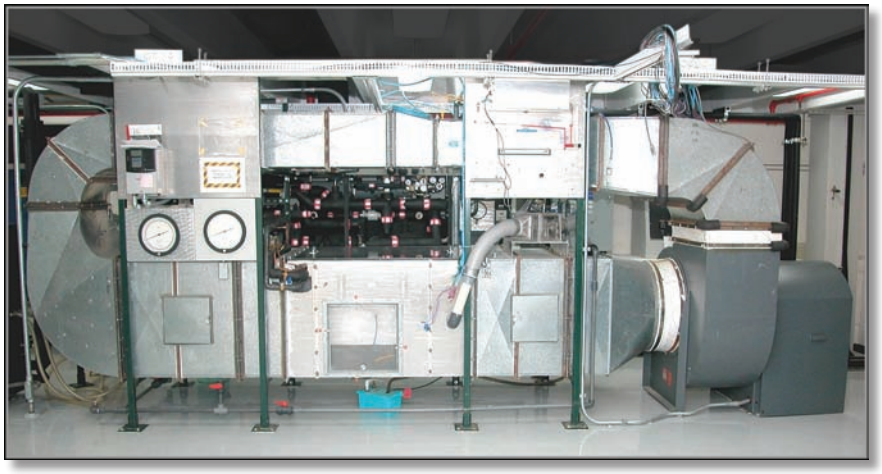
Microchannel heat exchanger analysis (courtesy of COMSOL).

Two wind tunnels—one for high temperature (550°C) and the other for medium temperature (325°C)—simulate temperature levels and air flow rates from engine-driven power generators and microturbines. A third wind tunnel is used for low-temperature applications.

continued on p.11

ORNL researchers are designing microchannel heat exchangers for use in a 10-ton rooftop refrigeration unit fueled by natural gas. The goal is a heat exchanger design that will reduce the profile of the unit so that it can be installed on a rooftop. Some microchannel heat exchanger designs are prone to refrigerant maldistribution resulting from the heat exchanger orientation or header design. Maldistribution reduces heat exchanger capacity so that units must be larger and more expensive. ORNL will investigate several designs, using a thermal imaging camera to evaluate and correct the maldistribution.

Low-temperature wind tunnel.



Future research will concentrate on greater improvements using enhanced materials, such as graphite fiber, and advanced concepts, such as rotating heat exchanger designs. The HTTL also will add more detailed experimental and analytical tools, such as multiphysics modeling capabilities using partial differential equations and flow visualization techniques.

For more information, see www.avalonconsulting.com/chpdemo/index.htm

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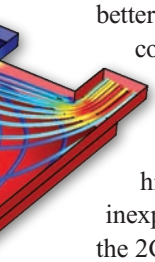
Sponsor: DOE/EERE Distributed Energy Program

Building the Next Generation of Superconducting Wires

Second-generation (2G) high-temperature superconducting wire technology is poised to begin replacing copper wire in power applications. Earlier superconducting wire, using bismuth-based copper oxide materials, vastly outperforms conventional conductors. However, 2G wires of yttrium-barium-copper oxide (YBCO) offer even better performance, as well as potentially competitive costs.



ORNL's RABiTS (rolling-assisted biaxially-textured substrates) technology, which produces thin, highly crystalline YBCO coatings on inexpensive nickel-alloy tapes, advanced the 2G technology. Now ORNL is helping ramp up the current-carrying capacity of superconducting coatings through nanostructural refinement of the material.

In a fully stabilized insulated wire, the superconducting layer is less than 1/20th as thick as a human hair; yet each wire strand must carry over 100 A of current—100 times as much as a copper wire of equivalent size. Applying a thicker coating increases the current capacity but degrades the superconductor, compromises properties such as mechanical flexibility, and requires longer processing times.

Oddly enough, superconducting wires need nanoscale material defects, since a perfect crystal will not support a useful critical current. The reason is the interaction of the flowing current with magnetic field lines that penetrate into the superconductor during use. In superconductors, nanoscale filaments of magnetic field are confined by swirling supercurrents called "vortices." Energy is lost when the current pushes on an array of vortices, causing them to move and dissipate energy, much like a normal resistor. Material defects that match the size and density of the vortex array tend to "pin" it in place, allowing current to flow at higher levels without moving the vortices.

ORNL researchers are using novel processes to tailor the YBCO nanostructure: either adding nanoscale components that are chemically inert with YBCO or inducing natural crystalline defects in the film as it forms. Both approaches dramatically improve superconducting properties, nearly doubling critical current densities at practical magnetic field levels. These enhancements could enable the wire fabrication process to require less superconductor and less processing time and improve mechanical properties. For more information, see www.ornl.gov/sci/oetd/index.htm.

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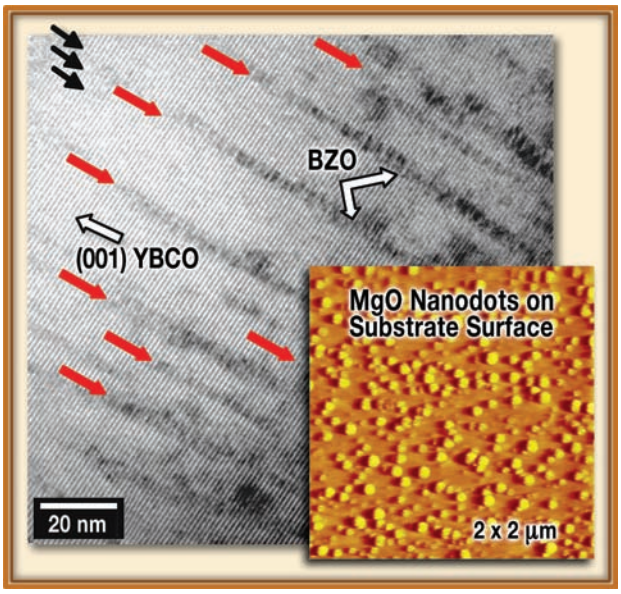
Sponsor:DOE Office of Electricity Delivery and Energy Reliability



Images of the nanoscale defects that can improve the current-carrying capacity of superconducting wires.

News Briefs

Das Authors MMMS Best Paper

Sujit Das of the Engineering Science and Technology Division at ORNL has received the Minerals, Metals, and Materials Society's 2005 Light Metals Division JOM Best Paper Award.

Sand Shares in R&D 100 Award

Jim Sand of ORNL's Engineering Science and Technology Division is among the recipients of the 2005 R&D 100 Awards, presented annually by R&D Magazine to recognize the year's most significant technological developments. The SEMCO Revolution, developed by SEMCO, Inc., and ORNL, is a rooftop packaged space-conditioning and ventilation system that can independently control indoor humidity and temperature and deliver any specified percentage of ventilation air into a building.

Jim Sand with a test unit of the Revolution space-conditioning system.

Ludtka Chosen ASM Fellow

Gerry Ludtka of the Metals and Ceramics Division recently was elected a fellow of the American Society of Metals International for his research in advanced materials and phase transformation.

Cleaner Fuels continued from p.5

The study showed that the low-sulfur fuels (ultra-low-sulfur, Fischer-Tropsch, and biodiesel) had no negative effect on engine efficiency for the unmodified engine. In fact, there was some performance improvement with the Fischer-Tropsch fuel. The latter also reduced the NO_x emissions. The Fischer-Tropsch, JP-5, and biodiesel fuels reduced PM emissions by at least 25%. The Fischer-Tropsch fuel also exhibited the lowest levels of toxicology-relevant compounds such as aldehydes.

The Navy used the results of the ORNL study to identify fuels to consider for an upcoming vessel evaluation. The low-sulfur diesel fuels, in particular, will be a focus for the engine experiments.

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Sponsor: DOE/EERE State Partnerships Program

In This Issue:

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