Science & Technology HIGHLIGHTS

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ZEBRAlliance Campaign Under Way

The Zero Energy Building Research Alliance (ZEBRAlliance) is both a series of research projects and a campaign to disseminate what is learned. The initial projects are residential and involve finding affordable ways to build or retrofit homes so they use less energy. The "miles per gallon" metric for homes is the Home Energy Rating System, or HERS rating, which is like a golf score—the lower the better. Once affordable low-HERS solutions are found, the alliance educates consumers, builders, contractors, and others and persuades them that low-HERS ratings are valued in the market and can be delivered.

A series of four ZEBRAlliance research houses are currently being implemented as a public-private partnership. Schaad Companies is paying for the land, bricks, and mortar and is collaborating with BarberMcMurry Architects and experts at Oak Ridge National Laboratory (ORNL) on the advanced feature designs. The U.S. Department of Energy (DOE) and the Tennessee Valley Authority (TVA) are sponsoring ORNL's design assistance, data collection and analysis, model development and validation, documentation of research results, and education and outreach efforts. Numerous ORNL industry partners that supply materials, components, equipment, and appliances to the housing industry are also collaborating in various ways. The houses will be available for research purposes for 30 months before they are sold and occupied. Through the focused efforts of the alliance members, a variety of energy-efficient components and whole-house construction techniques will be tested in order to provide homeowners, builders, and contractors with the information they need to buy and deliver more-energy-efficient new and existing homes.

Each ZEBRAlliance research home will provide about 2,800 square feet of living space. Construction of a home's shell or envelope—the part that separates the inside from outdoors —can have an enormous impact on energy use. Each home will be evaluated on the affordability and performance of one of the following strategies:

Rendering of proposed ZEBRAlliance home.

- Structural insulated panels consisting of a foam core of insulating material with oriented strand board skins.
- An advanced stick-built wood framing system designed to reduce thermal short circuiting through structural members, provide cavities for ample thicknesses of insulation, incorporate a radiant barrier in the attic, and achieve airtightness through use of a Henry™ liquid-applied, weather-resistive barrier.
- An insulating system that stores solar energy, shaving peak cooling loads by day and passively heating by night, coupled with other envelope features to achieve airtightness and weather resistance.
- A conventional wood framing system with the insulation wrapped around the outside to eliminate thermal short circuiting through structural members and use of a trowel-applied, weather-resistive barrier.

During the ZEBRAlliance groundbreaking on September 29, 2008, Jennifer Banner, CEO of Schaad Companies, remarked that a new era has just begun. "Working together, the ZEBRAlliance is changing the future of home building today," Banner said. She also described how new construction methods and materials are needed in the building industry in the same way that new types of smarter, more-fuel-efficient engines are needed for automobiles. "Intelligent, cost-effective innovation is powering the ZEBRAlliance," she said.

The homes, located in a residential community only minutes from ORNL, will be the first to field-test several new products over the next two years, such as the ClimateMaster™ ground-source integrated heat pump, a single unit in lieu of separate heating and cooling;

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L to R: Deputy Associate Laboratory Director, ORNL Energy and Engineering Sciences Directorate, Ted Fox; CEO, Schaad Companies, Jennifer Banner; Research Project Manager, TVA, Jeromy Cotten; Assistant Manager for Science, DOE ORO, Johnny Moore; Mayor, city of Oak Ridge, Tom Beehan; and Director, ORNL Partnerships Directorate, Tom Ballard.

ORNL Dedicates 51.25 kW Solar Photovoltaic Array

At the ribbon cutting. L to R: ORNL Associate Laboratory Director Dana Christensen; Tom Key, Electric Power Research Institute; Dave Peters, Johnson Controls; ORNL Director Thom Mason; Johnny Moore, DOE ORO; and Steve Johnston, Lightwave Solar.

The second-largest solar photovoltaic array in the state of Tennessee was formally dedicated at ORNL on Thursday, January 22, 2009. (The largest is an 87 kWp DC TVA system installed at Finley Stadium in Chattanooga.) The array, constructed during the summer of 2008, began producing power on September 30. The official dedication was scheduled so that it could be combined with the rollout of ORNL's Sustainable Campus Initiative and concurrent Energy Savings Performance Contract with Johnson Controls. ORNL has additional solar installations in place and planned for the campus that should soon make ORNL the largest single solar electricity generation site in the state of Tennessee.

Lightwave Solar Electric, a Nashville-based solar installer certified by the North American Board of Certified Energy Practitioners, installed the photovoltaic array. The solar array, constructed from 168 Sunpower 305 photovoltaic modules, is 87.8 m long and stands 3 m high. These modules are among the highest efficiency (18.7%) and highest capacity (305 W) presently available.

The solar array will produce 51.25 kW (peak) direct current and is expected to generate more than 65 MWh of electricity in an average year. The electricity generated by the array is connected to the ORNL electric grid and supplies the Building Technologies Research and Integration Center (BTRIC). In conjunction with the energy savings measures already implemented in the BTRIC, the array is expected to supply well over half of the annual energy requirements for one of the buildings in the BTRIC complex. The installation of additional solar capacity and enhanced energy improvements are planned for the BTRIC in an effort to establish the first zero-energy commercial building on the ORNL campus and in the state of Tennessee, and to establish the BTRIC complex as a zero-energy campus within ORNL.

In addition to the direct energy benefit to ORNL, the electricity from the array is also available for research projects at the Distributed Energy Communications and Control (DECC) facility, which is co-located with the BTRIC. The DECC facility research is directed at reactive power compensation, grid stabilization, and advanced inverter development. The system is designed such that even during the research activities, the energy is still directed to the ORNL grid to offset energy use at the BTRIC.

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Sponsor: DOE EERE Solar Energy Technologies Program

ZEBRAlliance continued from p.1

water heater and dehumidifier; and new appliances from the Whirlpool Corporation. After construction of the homes is finished, ORNL researchers will collect data, perform analysis, develop and validate models to generalize results, and document the affordable performance improvements achieved.

"This collaborative effort will serve the Tennessee Valley consumer with technologies and building techniques that will help them reduce their energy consumption, saving them money and reducing electricity demand across the valley," said Jeromy Cotten, TVA research project manager. "TVA's goal is to reduce the valley's electricity consumption by 1,400 megawatts by the end of 2012, and these new, efficient homes will help us meet that goal."

This initial ZEBRAlliance project marks a significant step toward moving the zero-energy homes effort by ORNL, funded from the beginning by DOE and TVA, from Habitat for Humanity houses in Lenoir City, Tennessee, to houses more typical of the region's mass market. The collaboration with Habitat for Humanity resulted in construction of five near-zero-energy houses from 2002 to 2007 and produced valuable information for improving future houses.

Through development of new technologies, fine-tuning existing ones, and combining partners' resources, the ZEBRAlliance seeks to continue to lower energy costs and make the technologies more affordable. The goal is to eventually lay groundwork for a house that could generate more energy than it consumes over a year but that would cost the same to purchase and own as a typical home.

"We commend Schaad for its leadership among Tennessee builders in joining the DOE Building America program's Builders Challenge," said Johnny Moore, assistant manager for science, DOE Oak Ridge Operations. "This project will accelerate DOE's progress toward its goal of zero-energy homes. It is a great example of science, government, and industry partnering to improve the energy efficiency of new and existing buildings."

Ted Fox, deputy associate laboratory director of the ORNL Energy and Engineering Sciences Directorate, said "ORNL is proud to be leading the development and integration of new, energy-saving residential technologies as a partner in this alliance. Without the sponsorship of the DOE Building Technologies Program and TVA, these achievements would not be possible."

For more information about the research project and partnership opportunities, go to www.zebralliance.com.

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Sponsors: DOE EERE Building Technologies Program, Tennessee Valley Authority, Schaad Companies

Titanium Door for Next-Generation Humvee Displayed

Whether for stopping cars or bullets, titanium is the material of choice because of its high strength and light weight, but it has always been too expensive for all but the most specialized applications. That could change, however, with a nonmelt consolidation process being developed by ORNL and industry partners. The new processing technique could reduce the amount of energy required and the cost to make titanium parts from powders by up to 50%, making it feasible to use titanium alloys for brake rotors, artificial joints, and armor for military vehicles.

Craig Blue (left) and Bill Peter with a Humvee door and other samples made from titanium powder produced by the award-winning Armstrong process.

A door panel fabricated from titanium powder for the Land Combat System Vehicle (the next-generation Humvee) was displayed in April 2008 at the Tactical Vehicles Summit in Arlington, Virginia. The door was made from titanium powder produced by the Armstrong process, an R&D 100 award-winning technique that produces the powder at low cost. ORNL's Bill Peter and Craig Blue presented the results of this work at the summit.

EERE's Industrial Technologies and Vehicle Technologies programs in partnership with the Defense Advanced Research Projects Agency and two private companies, BAE Systems and Ametek, have contributed to the fabrication of the door panel. Direct fabrication of sheet titanium from the low-cost powders was first demonstrated at ORNL. The sheets have mechanical and chemical properties that are comparable with those of ASTM wrought titanium.

The new Humvee door panel is lighter and stronger and is amenable to near-net-shape manufacturing. According to Bill Peter, by using a titanium alloy for the door, BAE Systems was able to reduce the weight of its vehicle while decreasing the threat of armor-piercing rounds. The lightweight alloy also improves the operation of the door and increases mobility of the vehicle, making it even more useful to the military.

Peter noted that the nonmelt approach, which includes roll compaction for directly fabricating sheets from powder, press and sinter techniques to produce net shape components, and extrusion, offers many advantages over traditional melt processing. The new method will enable the production of new alloys and composites. In addition, it saves a tremendous amount of processing energy and greatly reduces scrap. In coming years, researchers expect lightweight, corrosion-resistant titanium alloys to make their way into many other products, including automobiles, which will benefit because decreased weight improves fuel economy.

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Sponsors: DOE EERE Industrial Technologies and Vehicle Technologies Programs

First Southeast Industrial Energy Efficiency Summit Hosted at ORNL

On June 4 and 5, 2008, the ORNL Industrial Technologies Program and the Partnerships Directorate hosted the first Southeast Industrial Energy Efficiency Summit at ORNL. The summit featured keynote speaker Alexander "Andy" Karsner, then the assistant secretary, DOE Office of Energy Efficiency and Renewable Energy. Other speakers included Doug Kaempf, program manager, DOE Industrial Technologies Program, along with Michelle Buchanan, ORNL associate laboratory director for Physical Sciences, and Jim Roberto, then ORNL deputy director for Science and Technology. The summit had 77 attendees, including 53 from industry. The group met to begin developing an action plan to reduce the energy intensity of the industrial sector in the Southeast by 25%. Participants heard how four energy-efficiency leaders had reduced energy intensity in their companies, learned how three regional utilities work with their customers to improve energy efficiency, and met in groups to build an action plan for a Southeast Industrial Energy Efficiency Collaboration.

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Sponsors: DOE EERE Industrial Technologies Program and ORNL Partnerships Directorate

Can Aging Cars Tolerate More Ethanol from Gas Pumps?

Most cars on U.S. highways today have internal combustion engines that operate well on a fuel mixture that is approximately 90% gasoline and 10% ethanol and that is available at many gas stations today. Ethanol at this concentration, called E10, was first known as "gasohol" when used in limited quantities in the early 1970s and when made legal in 1979 by the U.S. Environmental Protection Agency (EPA) for use in all cars and engines.

The other form of ethanol fuel available today is E85, which is 85% ethanol. However, it can be legally used only in the estimated seven million flex-fuel vehicles currently in the United States. Unfortunately, the market for and economics of E85 have resulted in a slow growth in the number of E85 retail outlets; only about 1,700 of the 168,000 gas stations in the United States today offer E85. About 99% of ethanol used in fuel for cars and engines today is in the form of low-level (~10%) blends.

The Energy Independence and Security Act of 2007 calls for these actions: move "the United States toward greater energy independence and security" and "increase the production of clean renewable fuels." Specifically, the law requires use of 36 billion gallons of renewable fuel by 2022 to replace gasoline made from imported oil. Because ethanol, derived mostly from corn in the United States, is the most widely used renewable fuel in the U.S. transportation sector today, this alcohol fuel will likely compose a significant portion of the 36-billion-gallon requirement. Recognizing the limited E85 infrastructure, the U.S. Department of Energy (DOE) turned its attention to the feasibility of increasing the allowable ethanol content in gasoline to between 10% and 20%.

In 2007 DOE initiated a project to understand the effects of fueling the older "legacy" cars still in America's fleet with an intermediate gasoline-ethanol blend in which ethanol composes 15% to 20% of the mixture. The change to a higher blend level requires approval by EPA and must meet the requirement of the Clean Air Act that use of a particular fuel in a vehicle must not damage its emission control system. To be successful in practice, use of intermediate blends must be shown to be otherwise harmless to the operability and durability of cars and gasoline-powered engines such as those used for recreation and care of lawns.

Data from ORNL's instrumented chassis dynamometer tests of cars and engines fueled with increasing amounts of ethanol were cited in the first petition to EPA to legalize use of E15 fuel.

Through a variety of experiments, DOE has been evaluating and comparing the effects of gasoline (E0), E10, E15, and E20 on tailpipe and evaporative emissions, vehicle drivability under extreme conditions, engine operability, and compatibility with ethanol and durability of emission-control catalysts and materials in the engine and vehicle. Some projects are complete, many are still under way, and some have been deferred until additional resources are available.

Results of tests on 16 vehicles and 28 small non-road engines were recently reported by Brian West, Ron Graves, and Tim Theiss, all of ORNL, in collaboration with researchers at the National Renewable Energy Laboratory (NREL) in Colorado and Battelle Memorial Institute in Ohio. They investigated the effects of E0, E10, E15, and E20 on 16 popular, late model vehicles (1999–2007) and 28 small nonroad engines in power washers, grass trimmers, leaf blowers, and generators. In the future, other nonautomotive engines will be tested, such as those in snowmobiles, motorcycles, motorboats, and all-terrain vehicles (ATVs).

Several of the vehicles were tested on the chassis dynamometer at ORNL's Fuels, Engines, and Emissions Research Center (FEERC), in Knoxville, Tennessee. Others were tested in Aurora, Colorado, in partnership with NREL staff, and the remaining vehicles were tested under subcontract at the Transportation Research Center (TRC) in Ohio. A chassis dynamometer is an apparatus that allows a vehicle to be driven over a prescribed test cycle in a laboratory environment, while attached instruments measure emissions, fuel consumption, and other parameters, such as exhaust temperature.

In the fall of 2007 results from short-term tests of several small nonroad engines were provided to EPA and DOE.

In the full-life experiments at TRC, engines were run for their full useful life (50, 125, 300, or 500 hours) with a dedicated fuel. These experiments concluded in May 2008, and results were reported in October 2008.

Results of the small nonroad engine tests showed that boosting ethanol content caused increases in both operating temperatures and nitrogen oxide (NO_x) emissions. However, hydrocarbon (HC) and carbon monoxide (CO) emissions tended to decrease with increasing ethanol content in the fuel. These results were expected because these small engines are open-loop engines. Open-loop engines do not use exhaust-sensing feedback to control the fueling rate. In other words, their carburetors do not adjust the fueling to account for the oxygen in the ethanol (C_2H_6O). Because oxygen is present in ethanol, the fuel has a lower heating value—about two-thirds that of conventional gasoline. Therefore, about 3.5% more E10 or 7% more E20 is required to equal the energy content in a given mass of gasoline or maintain the same air-to-fuel equivalence ratio.

Open-loop engines are commonly air-cooled and customarily operate rich of stoichiometry (in the fuel-rich regime) to achieve cooler combustion temperatures. Stoichiometric combustion means that complete combustion would result in only water vapor and carbon dioxide emissions. Fuel rich means that more fuel is available than theoretically required, resulting in unburned fuel (HC) and CO emissions. With a fixed-fueling calibration, as ethanol content is increased, the relative combustion stoichiometry changes to a leaner (or less rich) equivalence ratio, leading to higher combustion temperature and hence higher component temperatures.

Despite the higher operating temperatures, none of the engines failed in response to increased ethanol fueling in the full-life aging experiments. But it should be noted that full-life hours in a laboratory setting over a few weeks are probably not as severe as field aging, in which the engines are exposed to dust, dirt, and extreme temperatures over several years.

The leaner mixture caused increased idle speed in some small engines, such as the line trimmers, leading to unintended clutch engagement, a potential safety concern on equipment such as chainsaws or hedge trimmers. Adjustments to the carburetors on the engines tested were able to bring the idle speed back down to the specified limit. However, it is not clear whether this adjustment would be possible on all engines.

Results of the vehicle tests showed that fuel economy decreased linearly with increasing ethanol content, as expected. No statistically significant changes in NO_x or nonmethane organic gas emissions were found. Acetaldehyde and ethanol emissions rose with increasing ethanol in the fuel blend, as expected.

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CF8C-Plus Steel Approved as New ASTM Alloy Grade

To meet the performance demands of higher fuel efficiency and reduced emissions for future advanced on-highway diesel engines, Caterpillar, Inc., and ORNL entered into a cooperative research and development agreement (CRADA) to develop new cost-effective materials for diesel exhaust components. Through the CRADA, ORNL and Caterpillar developed a new modified cast stainless steel, CF8C-Plus, that has exceptional high-temperature properties (resistance to creep-rupture, fatigue, thermal fatigue, aging, and oxidation) and a cost that is similar to that of the standard CF8C steel grade and five to seven times less than that of nickel-based superalloys. In addition, the alloy is weldable, requires no heat treatment after casting, and can withstand repeated thermal cycling at temperatures up to 900ºC.

In 2003, CF8C-Plus received an R&D 100 award. Late in 2006, Caterpillar commercialized CF8C-Plus for use as the Caterpillar Regeneration System (CRS) burner housing. CRS became standard equipment on all Caterpillar on-highway, heavy-duty, truck diesel engines in 2007. The CRS regenerates the ceramic diesel particulate filter and must withstand severe thermal cycling from 100 to 900ºC or above. To date, more than 400 tons of CF8C-Plus steel have been cast for the CRS application.

The commercialization opportunities for CF8C-Plus continue to grow. In December 2007, ORNL was awarded DOE EERE Technology Commercialization Funds to work with Caterpillar and Honeywell to qualify CF8C-Plus steel for diesel turbocharger housings. Stainless Foundry & Engineering signed the first nonexclusive commercial license with Caterpillar for casting CF8C-Plus for engine exhaust components in May 2008. In November 2008, CF8C-Plus was recognized as a new, commercial heat-resistant cast stainless steel grade, HG10MNN, by ASTM (including weldability qualification), further increasing the range of potential applications.

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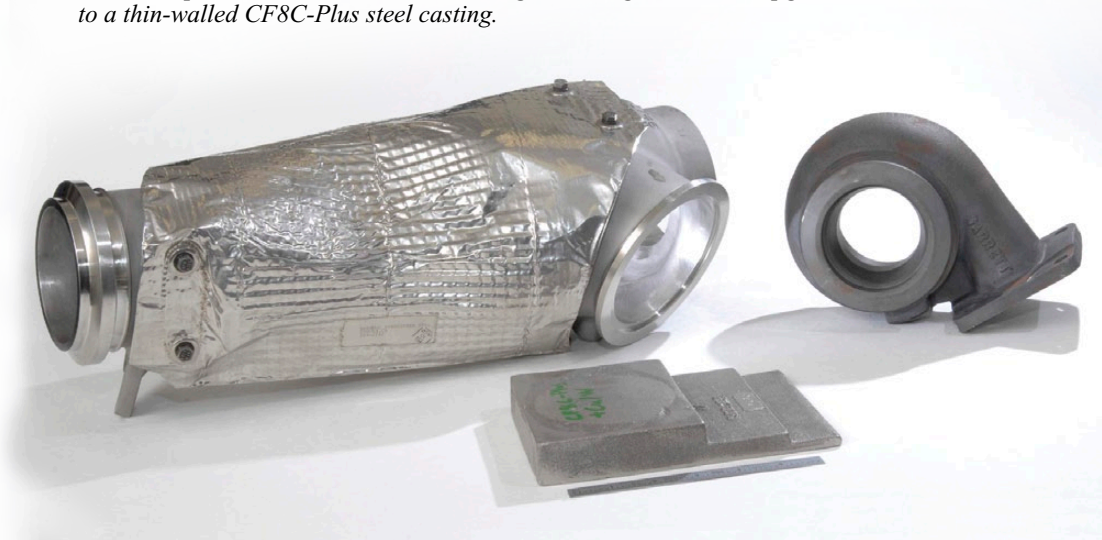
Sponsors: DOE EERE Vehicle Technologies and Industrial Technologies Programs

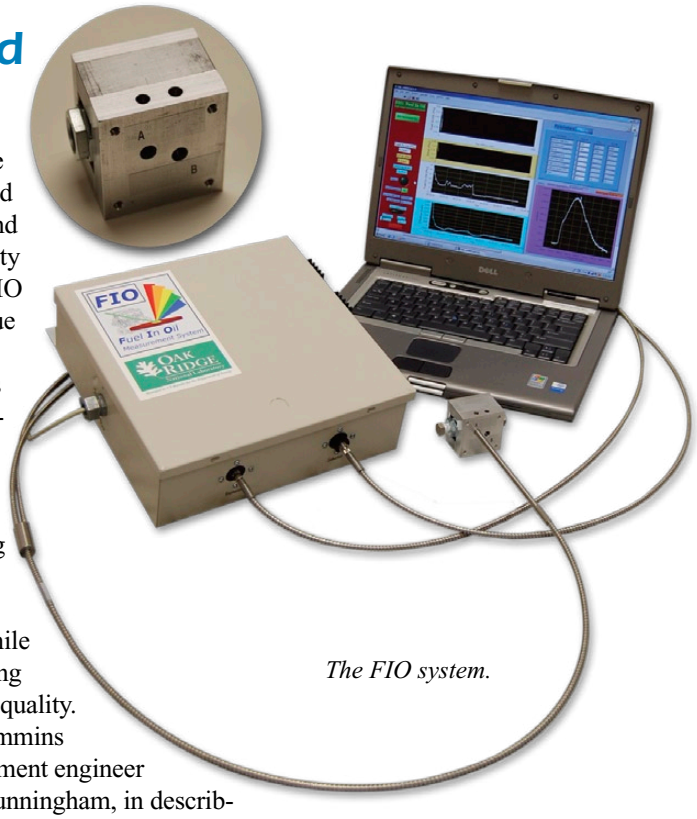
New CRS unit and step-castings made of CF8C-Plus cast austenitic stainless steel. Also pictured is a cast-iron turbocharger housing that can be upgraded to a thin-walled CF8C-Plus steel casting.



Oil Characterization Tool Being Used for Efficient Engine Development

ORNL has delivered a new tool for rapid measurement of fuel dilution in engine oil to Cummins, Inc., who has put it to use in development of efficient diesel engines. The tool was developed by Jim Parks and Bill Partridge, both of ORNL's Fuels, Engines, and Emissions Research Group, in close working association with Cummins technical staff in Columbus, Indiana, through a DOE-funded CRADA. The tool, called "Fuel in Oil" (FIO), uses laser-induced fluorescence spectroscopy to detect low levels of diesel fuel accumulated in the engine oil. A fiber-optic probe inserted into an oil line continuously monitors the fuel level in the oil by detecting the fluorescence signal from a dye added to the fuel in small quantities. The readily available dye, which is fully compatible with engine fuel systems, enables the technique to be highly sensitive to small changes in oil dilution.

Modern diesel engines use multiple fuel injection pulses that occur at different times in the engine cycle to simultaneously attain efficient combustion and low emissions. If not properly calibrated, the complex control of multiple injections can lead to oil dilution and its attendant effects on engine durability if not properly controlled. FIO enables development engineers to get rapid feedback on the effectiveness of prototype fuel injection strategies. The immediate feedback is extremely valuable, allowing the engineers to optimize many engine performance parameters, including fuel efficiency; emissions; noise, vibration, and harshness; torque; and power while minimizing oil dilution. Prior to the development of FIO, an off-line technique was used that required long (~8 hour) engine experiments for each set of engine parameters to generate a sample with enough fuel to be detected. The samples had to be sent for gas chromatographic analysis. In contrast, FIO makes measurements every 5 seconds, and a dilution rate can be obtained in approximately 10 to 15 minutes of engine run time in an engine test cell. The increased speed and sensitivity of the FIO technique greatly shortens development time, thereby reducing development costs while improving product quality.



The FIO system.

Cummins development engineer Mike Cunningham, in describing the tool, says, "The benefit of the FIO tool is that it allows the fuel dilution variable to be optimized during the calibration process along with torque, fuel economy, and emissions. Previously, the traditional oil dilution methods allowed us to check an existing calibration, and if undesirable levels were found, we were required to cycle back through the optimization process. We feel this tool will be essential to our calibration process."

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Sponsor: DOE EERE Vehicle Technologies Program

Wave of the Future: Distributed Energy and Power Electronics

In response to federal mandates to produce more electricity from renewable energy sources, the U.S. electrical utility industry is facing major changes. The dominant sources of electricity have long been large, centralized, fossil and nuclear power plants. The electric power has been carried long distances by high-voltage transmission lines from generation centers to cities, where it is converted to low-voltage power that is delivered to buildings, or "loads."

Electricity generation is increasingly decentralized because more electricity is being supplied directly from energy sources located at load sites. Such renewable, distributed energy (DE) sources include wind turbines, photovoltaic cells, biogas-fired microturbines, geothermal heat pumps, and hydrogen fuel cells.

In an alternating current (ac) power system, both active power and reactive power are present. Active power is the electrical current component that delivers energy from the source to the load. All resistive loads, such as electric lights, consume active power. Although reactive power is the current component that flows back and forth between the source and load, this power form does not transport any energy. Instead, reactive current flow causes additional energy losses from the grid.

Power electronics interfaces are necessary for most DE resources because the output current—excess current that the DE resource owner wishes to sell to the utility—must be converted from dc to ac and at the appropriate voltage level in order to be connected to a local utility's distribution system.

DE together with power electronics interfaces can control the flow of both active power and reactive power in real time. ORNL tests show that a DE device armed with an inverter can provide "dynamic reactive power" to distribution power lines that help regulate local voltage and improve power quality.

Unlike the reactive power from traditional generation centers' capacitor banks, the reactive power from DE is dynamic because an inverter can control it in real time. Inverter-based DE resources can provide a number of ancillary services to utilities, such as local voltage regulation, reactive power compensation, power factor correction, harmonics compensation, and network

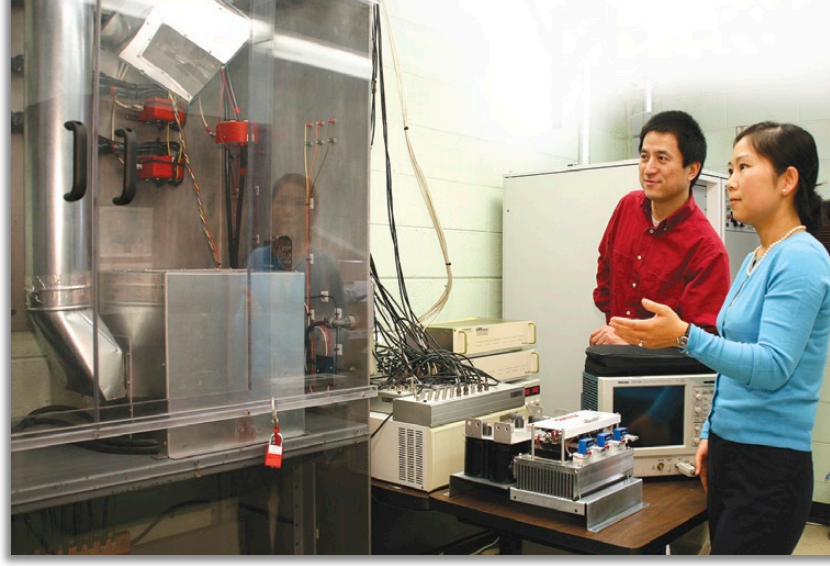
stability. These services would improve the electrical system's efficiency, stability, and reliability.

The electrical utility industry is interested in using DE systems as local sources of reactive power. The Distributed Energy Communications and Controls (DECC) Laboratory at ORNL provides a unique test bed for various DE systems.

At the DECC Laboratory researchers are testing the ability of inverter-based DE systems to realize full control of both active power and reactive power. Within DECC a small-scale distribution system is connected to a local ORNL substation that distributes electricity generated by the Tennessee Valley Authority to laboratory buildings. The DECC lab has a synchronous condenser, an inverter, and a microturbine generator. The combined generation of active power and reactive power from DE is under development. Other plans include installing photovoltaic panels on a charging station for testing whether the inverter in a plug-in hybrid electric vehicle can supply reactive power to the distribution system while the car's battery is being recharged.

In partnership with industry and academia, ORNL is performing research on evaluating the benefits of voltage regulation and motivating people using DE resources to provide voltage regulation to the utilities by selling both active and dynamic reactive power.

ORNL's industry partners view the use of DE for providing ancillary services as the wave of the future. For example, Southern California Edison, one of ORNL's utility partners, plans to implement DE technology in its "Distribution System of the Future" project. The California electric utility envisions using local inverter-based DE to supply more than 30% of its distribution system's needs for reactive power.



UT professor and ORNL researcher Fran Li (left) and ORNL researcher Yan Xu at the inverter test area in the ORNL Distributed Energy Communications and Control Laboratory.

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Sponsor: DOE Office of Electricity Delivery and Energy Reliability

ORNL-GE CRADA Signed for Hybrid Water Heater

In June 2008, ORNL and General Electric (GE) signed a CRADA for the commercial development of what promises to be a revolutionary appliance, the Hybrid Electric Water Heater. The device, which pulls heat from surrounding air to make hot water, will be the first tank-type water heater to achieve the new 2009 Energy Star rating. A commercial hybrid appliance would serve as a major component in affordable "zero-energy" homes. At the signing, GE's Henry Eng said that the units should be available to the public by late 2009.

ORNL's role in the collaboration will be to provide unbiased third-party performance validation (energy factor, first-hour recovery rating) and durability testing in the laboratory, performance validation testing in the field, development of modeling capabilities to supplement a hardware-based development approach, and assistance with design finalization based on testing and modeling results. DOE EERE Building Technologies is sponsoring ORNL; GE is covering its own costs within the CRADA (which compose about 80% of the total CRADA cost).

The Hybrid Electric Water Heater is expected to use 50% of the energy required by a conventional electric water heater, which is the second-largest consumer of energy in the home. The amount of money saved by a specific household each year will vary with hot water use. For average families paying10.4 ¢/kWh (the national average for residences in 2006 dollars, according to the 2008 *Buildings Energy Data Book* [DOE EERE, September 2008]), yearly savings would be $248 per year for a household of four and $122 per year for a household of two. Given that about 44 million electric storage water heaters provide hot water in American homes, savings would add up to 69 billion kWh/year, or $7.2 billion, if they were all replaced with the new product.

The Hybrid Electric Water Heater is described as a hybrid because it uses both a heat pump and traditional electric resistance heaters. Its technological roots can be traced to a previous product cycle sponsored by the DOE EERE Building Technologies Program. The heat pump water heater that resulted from that effort won an R&D 100 Award in 2001. ORNL was recognized along with team members EnviroMaster International LLC and Arthur D. Little (now TIAX LLC). Although production of the commercial product resulting from that effort (EMI's Watter$aver) ceased in 2005, the research at ORNL demonstrated the durability and efficiency-doubling aspects of using heat pumps to provide hot water and documented the importance of efficiency labeling, brand strength, home improvement center shelf space, and a national installation and service network.

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Sponsor: DOE EERE Building Technologies Program

Honors and Awards...

Daw, Goyal Named Fellows

Stuart Daw

Two researchers working under the ORNL EERE Program were among the three named ORNL corporate research fellows in 2008. **Stuart Daw**, of the Energy and Transportation Science Division, and **Amit Goyal**, of the Materials Science and Technology Division, were recognized for their sustained outstanding achievements in their fields. Being named a corporate fellow is the highest designation bestowed upon scientists and engineers at ORNL. The latest three appointments bring the total to 26.

Amit Goyal

Daw has pioneered the application of chaos theory and nonlinear dynamics to energy technologies, including gas-fluidized beds, internal combustion engines, and pulsed combustion.

Goyal's pioneering research has had a profound impact on the field of high-temperature superconductivity, both in fundamental materials science and in the transition of scientific discoveries from the laboratory to the marketplace.

Goyal was also one of six ORNL researchers to be elected a fellow of the American Physical Society in 2008. He is also a fellow of the American Association for Advancement of Science (AAAS), the World Innovation Foundation, the American Society of Metals, the Institute of Physics, and the American Ceramic Society.

FreedomCAR and Fuel Partnership Wins Plastics Engineers' Team Award

The FreedomCAR and Fuel Partnership, whose participants include DOE and USCAR, received the Society of Plastics Engineers (SPE) Automotive Division's 2008 Executive Leadership Team Award on November 20, 2008, at the Thirty-eighth Annual SPE Automotive Innovation Awards Competition and Gala in Livonia, Michigan. Members of the USCAR Automotive Composites Consortium were chosen by the SPE board of directors for their industry-leading innovation of advanced lightweight plastics and composite materials. Among the honorees was Charles David Warren, ORNL program manager for Transportation Materials and field technical manager for composites in DOE's Lightweighting Materials Program in the DOE Vehicle Technologies Program.

The award recognizes the collaborative research and development of the Vehicle Technologies Program in advancing polymer-based technologies as potential enablers for increasingly lightweight—and as a result, more fuel efficient—vehicle architectures.

"We are extremely pleased that the important industry-government collaboration represented by the FreedomCAR and Fuel Partnership is being recognized and honored by SPE International," said USCAR Executive Director Don Walkowicz. "The Partnership is essential to advancing sustainable transportation solutions for U.S. consumers and our global society. Our work is focused on helping our nation reduce its dependence on foreign oil. Advancing the development and automotive use of lightweight materials plays an important role in this effort."

S&T Highlights is a communication of Oak Ridge National Laboratory's *Energy Efficiency and Electricity Technologies Program, Transportation Technology Program,* and *Energy Materials Program.*

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OAK RIDGE NATIONAL LABORATORY
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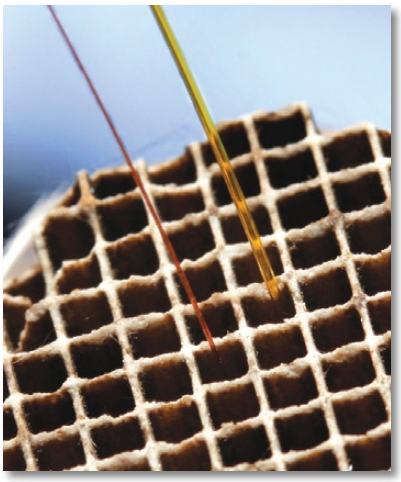


Two SpaciMS capillary sampling probes inserted in a channelized monolithic catalyst.

SpaciMS Wins Two Awards

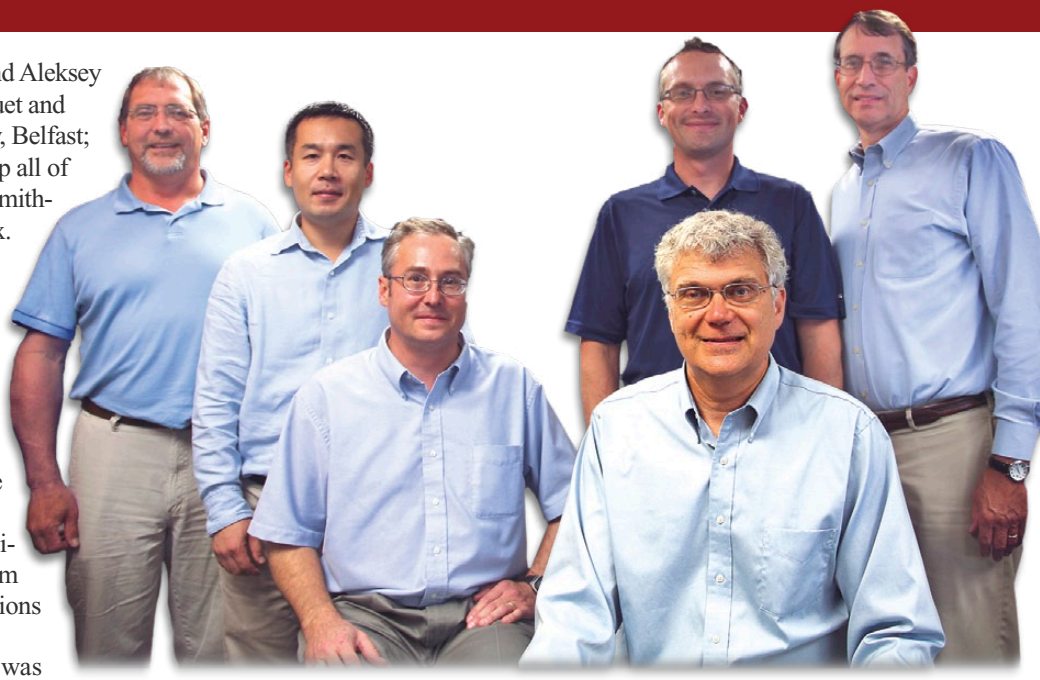
In 2008, *R&D Magazine* recognized the Spatially Resolved Capillary Inlet Mass Spectrometer (SpaciMS) with an R&D 100 Award. In 2009, SpaciMS won a Federal Laboratory Consortium Award for Excellence in Technology Transfer.

SpaciMS was developed by Bill Partridge, along with team members Jae-Soon Choi, John Storey, and Sam Lewis, all of the Energy and

Transportation Science Division; Neal Currier and Aleksey Yezerets, both of Cummins, Inc.; Alexandre Goguet and Christopher Hardacre, both of Queen's University, Belfast; David Lundie, Terry Whitmore, and Adrian Jessop all of Hiden Analytical; and Gerald DeVault and Bob Smithwick, both of the Y-12 National Security Complex.

SpaciMS takes gaseous samples inside the confined spaces of chemical reactors, such as automotive catalysts, fuel reformers, and fuel cells, and measures changes in transient chemical-composition distributions within the device. Sampling within the chemical reactor during operation provides greater understanding of the detailed device chemistry than has been possible previously by measuring chemical-reactor exhaust alone. This technology was used in the optimization of the groundbreaking 2007 Dodge Ram heavy-duty pickup truck, which met 2010 emissions control standards three years ahead of schedule.

Funding for the development of SpaciMS was provided by ORNL's Laboratory Directed Research and Development Program and DOE EERE Vehicle Technologies Program.



SpaciMS development team, L to R: Sam Lewis, Jae-Soon Choi, Bill Partridge, and John Storey, all of the Energy and Transportation Science Division, and Gerald DeVault and Bob Smithwick, both of the Y-12 National Security Complex.

David Greene

David Greene Receives "Unsung Hero" Award

On March 4, 2009, Tennessee Congressman Zach Wamp presented David Greene with the Alliance to Save Energy's "Unsung Hero" Award during Greene's induction into the Alliance's Energy Efficiency Hall of Fame. The award recognizes Greene's decades of effort to promote automotive fuel economy, including numerous research studies, service on three National Academy of Sciences committees investigating the potential to improve fuel economy in the United States, and development with ORNL and UT colleagues of the award-winning www.fueleconomy.gov website. The ceremony took place in the Dirksen Senate Office Building in Washington, D.C. Greene is a corporate research fellow in the Energy and Transportation Science Division and a visiting faculty member at the University of California at Davis Institute for Transportation Studies.

ORNL Staff Receive SAE Awards

Scott Sluder and Brian West, both of the Energy and Transportation Science Division, were honored by the Society of Automotive Engineers (SAE) recently. Sluder was named a 2008 recipient of the Forest R. McFarland Award, which recognizes individuals for their outstanding contributions to the work of the SAE Engineering Meetings Board. He was recognized for his contributions as a technical session organizer, reviewer, and strategic advisor to SAE's Powertrain, Fuels, and Lubricants Activity. SAE presented an "Outstanding Oral Presentation" award to Brian West for his talk entitled "Fuel Economy and Emissions of the Ethanol-Optimized Saab 9-5 Biopower" (SAE Paper 2007-01-3994). This is the third such award for West, so he will be receiving the Lloyd L. Withrow Distinguished Speaker Award at the 2009 SAE Congress.

Scott Sluder

Brian West

Organizational Announcements

Craig Blue Heads Energy Materials Program

Craig Blue has been named director of ORNL's newly formed Energy Materials Program. This program combines the ORNL EERE Industrial Technologies Program with the Fossil Energy Program and supports fundamental and applied energy-related materials research for the energy efficiency, renewable energy, fossil energy, and national security fields.

Ray Boeman Named TTPO Program Director

Ray Boeman has been appointed director of the newly formed ORNL Transportation Technology Program Office. The TTPO is responsible for R&D supporting the DOE EERE Vehicle Technologies Program; Hydrogen, Fuel Cells, and Infrastructure Program; and Biomass Program as well as transportation systems and infrastructure R&D supporting the U.S. Department of Transportation and its model agencies.

Tom King Named EEET Program Director

Tom King has been appointed director of the newly formed ORNL Energy Efficiency and Electricity Technologies Program. Tom will be responsible for R&D projects conducted for the DOE Office of Electricity Delivery and Energy Reliability and for selected offices within the DOE Office of Energy Efficiency and Renewable Energy.

Chad Duty Named Acting Head of Solar Energy

Chad Duty has been appointed the acting manager of the Solar Energy Technologies Program in the Energy Efficiency and Electricity Technologies Program Office. He coordinates and supports the broad spectrum of solar research at ORNL, from modeling the fundamental physics of photovoltaics and increasing solar cell efficiencies to reducing manufacturing costs, effectively integrating solar technologies with the power grid, and encouraging the implementation and use of solar technologies.

Joe Gracia Manages Program in EEET

Joe Gracia has been named manager of the Electricity Delivery Technologies Program within the Energy Efficiency and Electricity Technologies Program. Joe manages the research, development, and deployment activities in the areas of visualization and controls, power electronics and energy storage, renewable and distributed systems integration, and control system security.

Robin Graham Manages Biomass Program

Robin Graham has been named manager of the ORNL Biomass Program. The mission of the program is to help transform the nation's abundant and renewable biomass resources into a source for cost-competitive fuels, other biobased products, and power. In her new role, Graham provides scientific, technical, and program development leadership for EERE-funded bioenergy research across all ORNL directorates. She retains her position as leader of the Energy and Environmental Systems Science Group in the ORNL Environmental Sciences Division.

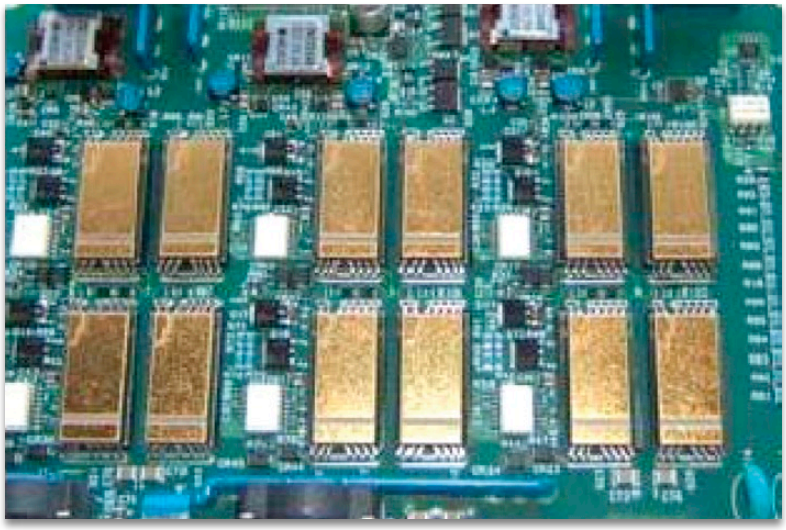
Brennan Smith Manages Wind and Water Program

Brennan Smith has been named manager of the Wind and Water Power Program at ORNL. This program focuses on water- and wind-related technology research, along with the integration of renewable energy technologies with power systems and the effect of these technologies on grid reliability.

High-Temperature Inverter for Electric and Hybrid Vehicles

ORNL researchers at the Power Electronics and Electric Power Systems Research Center, located at the National Transportation Research Center, are teaming with Delphi Corporation to develop a cost-effective, lightweight, high-temperature inverter for hybrid, plug-in hybrid, and fuel-cell vehicles. This work, which will span three years, will be carried out under a cooperative research and development agreement funded by the DOE Vehicle Technologies Program.

Inverters in these advanced vehicles are needed to take the power from the primary energy storage source and convert it into a form suitable for powering the electric motor. To gain market acceptance for the vehicles, the FreedomCAR and Fuel Partnership has set targets for the power electronics with regard to power density, volume, weight, and cost. Significant efforts to reduce costs are required to make the vehicles competitive in the marketplace and attractive to consumers. One method that automakers think will reduce overall system cost is to eliminate the auxiliary cooling loops necessary to keep the power electronics running cooler. Presently, commercial hybrid electric vehicles use an additional 70ºC loop, pump, and radiator to cool the high-power, high-heat-producing electronics in the inverter. Designs to eliminate this costly loop are being explored. Using the existing engine coolant, which reaches temperatures of about 105ºC, is a solution preferred by the automotive manufacturers. However, these elevated operational temperatures present unique challenges to the power electronics with regard to achieving acceptable operational performance and reliability.



PC board populated with Viper modules. Image courtesy of Delphi Corp.

The goal of the effort at ORNL is to produce a manufacturable inverter that operates reliably for 15 years and that meets cost, volume, and weight targets. The effort will involve the coordination of a core team of researchers at ORNL who will work to define an optimal circuit topology and will assist Delphi in device modeling, circuit simulations, and validation testing. Dow Corning and GeneSic will work together on the development of new devices that will be able to function at high temperatures. Argonne National Laboratory and General Electric will contribute to the project through their expertise in the development of capacitors, which are major contributors to the volume and cost of present-day inverters.

Paramount to this effort is Delphi's parallel packaging effort to produce an inverter with fewer parts, thus reducing manufacturing steps and cost. The development of a high-volume inverter with high-performance thermal technologies that conforms to standard manufacturing processes is a key element of the program. To this end Delphi has developed a novel method of packaging semiconductor devices, designated "Viper Technology."

The Viper concept involves the use of a semiconductor die with solderable connections on both the front and back, thus eliminating traditional wirebonds and providing the capability to cool both sides of the module. This innovation will allow for higher junction temperature operation. The semiconductor dies are embedded in the Viper module, and connections are brought out on leads that resemble old dual in-line packaged semiconductor configurations.

Through the use of topology innovations, novel packaging concepts, new high-temperature semiconductors, and new capacitor technologies, the next generation of power electronics will enable the move to vehicles that will have better fuel efficiency. The Vehicle Technologies Program is leading efforts to propel these developments in the vital mission to reduce U.S. dependence on foreign oil.

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Sponsor: DOE EERE Vehicle Technologies Program

Aging Cars continued from p.5

Seven of the 16 vehicles running on E15 or E20 exhibited higher temperatures in both the exhaust and catalyst under full throttle operation. The additional thermal effects might contribute to more rapid catalyst deterioration. Full-life (120,000 mile) vehicle studies are under way to investigate this issue.

The ongoing test program is co-led and funded by DOE's Office of Energy Efficiency and Renewable Energy (EERE) Biomass Program and the EERE Vehicle Technologies Program, with technical support from ORNL and NREL. DOE and the national laboratory team have worked closely with representatives from EPA, U.S. auto manufacturers, engine companies, and other organizations to develop and conduct a robust test program.

The first formal petition to legalize the use of E15 as a fuel for cars and small engines was recently submitted to EPA. The petition contained numerous citations of the data in the ORNL-NREL report.

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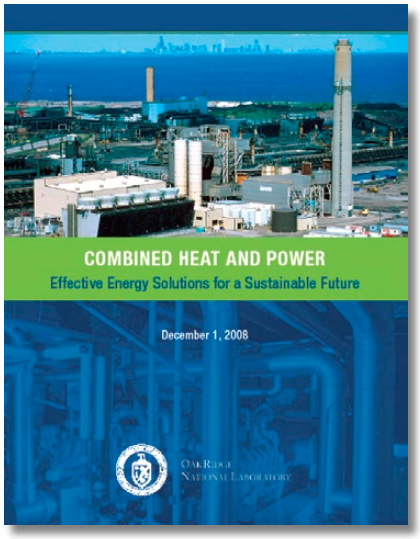
Sponsors: DOE EERE Biomass and Vehicle Technologies Programs

Cover Stories



ORNL Releases CHP Report

ORNL recently released *Combined Heat and Power: Effective Energy Solutions for a Sustainable Future*, a report from the Industrial Technologies Program's Industrial Distributed Energy Activity. The report, coauthored by ORNL's Patti Garland, outlines the environmental, energy, business, and infrastructure advantages of combined heat and power (CHP) technology over conventional electric and thermal generation. The report also quantifies the national benefits of reaching a proposed 20% of generation capacity using numerous CHP technologies. The report provides an in-depth discussion of current opportunities and challenges for more widespread national CHP deployment and sets the stage for future policy dialogue aimed at promoting this clean energy solution.

Report on CHP Applications in Data Centers

In March 2009, ICF International completed a report, *Opportunities for Combined Heat and Power in Data Centers*, for Oak Ridge National Laboratory and the DOE Office of Energy Efficiency and Renewable Energy Industrial Technologies Program. Data centers in commercial, educational, and governmental facilities consume 1.5% of all the electricity used in the United States. They are rapidly growing, and their demand for energy is also expected to grow. The report identifies opportunities for applying combined heat and power (CHP) technologies as an adjunct to primary power for data centers, thus making them more cost-effective and energy efficient and reducing the pressure on the electrical transmission and distribution infrastructure in the United States.

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