Science & Technology HIGHLIGHTS

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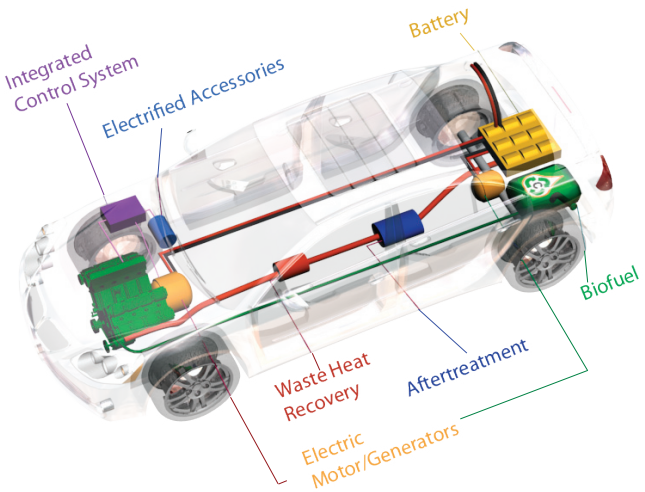
ORNL Involved in Two U.S.-China Clean Energy Research Centers



Biofuel-electric hybrid engine (courtesy of the University of Michigan)

ORNL is participating in two of three recently announced joint U.S.-China Clean Energy Research Centers (CERCs). ORNL was chosen because of its renowned expertise in building energy efficiency and transportation energy research.

In November 2009 in Beijing, President Barack Obama and President Hu Jintao jointly announced plans to establish the U.S.-China CERCs to reduce energy use and greenhouse gas emissions in both nations. These new partnerships "will create new export opportunities for American companies, ensure that the U.S. remains at the forefront of technology innovation, and help reduce global carbon emissions," said David Sandalow, Department of Energy Assistant Secretary of Energy for Policy and International Affairs, who announced the creation of the three CERCs.

ORNL is a partner in a U.S. consortium involved in the U.S.-China CERC for building energy efficiency (CERC-BEE), whose award was announced in October 2010. The consortium, led by the DOE's Lawrence Berkeley National Laboratory, is focusing on making buildings in both China and the United States more energy efficient, using the results of research conducted in both countries.

Besides the two DOE labs, the consortium partners include the Massachusetts Institute of Technology (MIT), the University of California-Davis, the National Resources Defense Council, the Energy Foundation, ICF International, the National Association of State Energy Officials, the Association of State Energy Research and Technology Transfer Institutions, General Electric, ClimateMaster, Saint-Gobain Corporation, Bentley, Dow Chemical, Honeywell, Pegasus Capital Advisors, and Schneider Electric.

American buildings account for nearly 40% of U.S. energy consumption and carbon emissions. Almost half the new floor space constructed annually in the world is built in China. As such, the United States and China will play key roles in the world's transition to an energy-efficient buildings sector.

"Both countries are doing a tremendous amount of work on energy efficiency in all energy-consuming sectors," said Michaela Martin, deputy director of the CERC-BEE consortium. "The CERC-BEE approach to collaborative research will accelerate this important work and lead to new efficient products and materials for the buildings markets in both countries."

Martin will manage ORNL's contributions to the R&D collaboration with industry partners and with Chinese counterparts. ORNL, which brought four industry partners into the consortium (including GE), will receive $3 million over 5 years to make contributions in advanced insulation systems; ground-source and distributed heat pumps; and building-integrated, solar, combined heat and power systems. Also involved in the project are ORNL's Therese Stovall, Xiaobing Liu, and Omar Abdelaziz, all of ORNL's Energy and Transportation Science Division.

Continued on p. 5

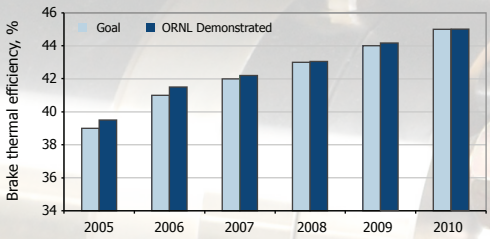
Modern buildings in Shanghai's skyline.

45% Efficiency Achieved in Diesel Engine Tests

Exhaust from diesel vehicles is fraught with promise and peril. The danger lies in its potentially hazardous pollutants and particulates. But exhaust also carries heat that could be recovered and converted to electricity for the vehicle.

ORNL has an active research program in support of improving "after-treatment" systems for the catalytic removal of gaseous pollutants in exhaust. Partnerships between ORNL and industry have been instrumental in furthering clean-diesel technologies so that they comply with U.S. emissions standards. German automakers sell diesel passenger cars and SUVs, and U.S. automakers manufacture diesel pickup trucks.

In 2010 an ORNL team led by Tom Briggs demonstrated that the "peak brake thermal efficiency" of a light-duty diesel engine (passenger car or pickup truck) could be improved to 45% by converting exhaust heat into electricity. In other words, 45% of the energy in the diesel fuel was usable for driving the vehicle and powering its accessories. By comparison, passenger-sized commercial diesel engines today achieve an efficiency of approximately 41% and a gasoline engine averages approximately 33%.



Bar chart shows ORNL's success in meeting or exceeding DOE goals for diesel engine improvements.

Since 2005 ORNL teams have met or exceeded the Joule milestone in vehicle energy efficiency and emissions limits established by the Department of Energy. "Every year we added a different technology," said Robert M. Wagner, previous team leader and acting director of ORNL's Fuels, Efficiency, and Emissions Research Center at the National Transportation Research Center. "We focused on engine optimization, improvement in fuel properties, electrification of components, better lubricants, and recovery of heat from exhaust to power a diesel vehicle's air conditioner, water pump, or radio."

The ORNL team developed an organic Rankine cycle, or miniature power plant, which recovers heat from the exhaust and uses it to boil a liquid refrigerant to turn a turbine as the vapor drops in pressure, generating power. The initial system size is laboratory scale. The components must be downsized and packaged properly to fit in a diesel car and enable part-load performance—a mix of idling, stop-and-go city driving, and steady-state cruising at highway speeds. The ORNL team found that energy recovery is significant at high load when the vehicle engine in a test cell is run at high speeds for a long time.

For years automaker executives were skeptical that heat recovery could increase light-duty vehicle efficiency. According to Wagner, at a November 9, 2010, meeting of USCAR (U.S. Council for Automotive Research), the ORNL efficiency achievement was highlighted as the principal accomplishment by USCAR's Advanced Combustion and Emissions Control technical team. "Our achievement was communicated to the directors of USCAR, who represent General Motors, Ford, and Chrysler," he said.

In parallel with the experiments, K. Dean Edwards of ORNL's Energy and Transportation Science Division developed computer models of the organic Rankine cycle in combination with a diesel engine model. The model includes appropriately sized heat exchangers, an expander, a turbine, and other components.

"We are partnering with industry to do more experimental and modeling work," Briggs said. "Industry and universities are showing major interest in our models. The models let us predict over the drive cycle the fuel economy the buyer would get in a vehicle with an exhaust heat recovery system."

Although heat recovery system components would improve fuel economy, they would also increase the vehicle's initial cost. "The models provided insights into which components are worth spending money on to get improved fuel economy," Wagner said. "Some components had minimal impact, and others had a major impact on the increase in efficiency."

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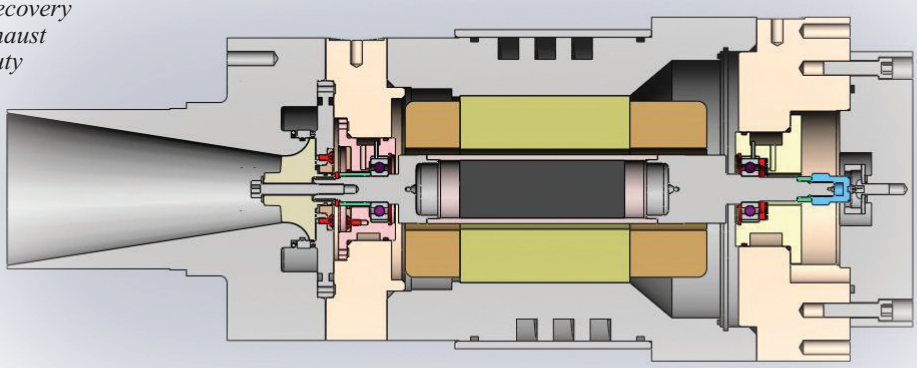
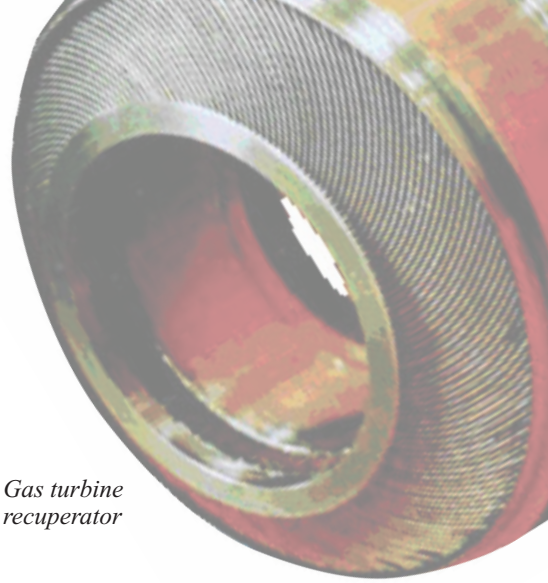
Sponsor: DOE EERE Vehicle Technologies Program

Background image: The ORNL design for the waste heat recovery system using exhaust from the light-duty diesel engine



Schematic of a Barber-Nichols diesel engine turbine that ORNL selected because of its integrated turbine-generator design. This proven design has been installed in multiple applications.

ORNL Steel Produced for Gas Turbine Tests



Gas turbine recuperator

Researchers led by ORNL's Mike Brady developed a low-cost stainless steel that possesses an unusual but long-needed combination of two properties: high resistance to both corrosion and deformation (creep strength) at high temperatures. Until now, only more-expensive, nickel-based alloys have had both desirable properties.

Now the challenge is to demonstrate that ORNL's alumina-forming austenitic (AFA) steel, which received an R&D 100 award from *R&D Magazine* in 2009 as one of the year's most significant technology innovations, can be scaled up for industrial production and commercial applications. ORNL is partnering with Carpenter Technologies, which manufactures iron- and nickel-based specialty alloys. Carpenter Technologies and ORNL have two cooperative research and development agreements (CRADAs) for fabrication of AFA steel and two joint projects with DOE's Industrial Technologies Program.

Bruce Pint, leader of the Corrosion Science and Technology group in ORNL's Materials Science and Technology Division, for which Brady works, is spearheading the effort to work with industry to scale up and commercialize the AFA steels. But, he noted, because every alloy producer needs customers to justify investments in new alloy development, identifying end users with promising applications is critical.

"Most companies realize they need new alloys to stay competitive and in business for a long time," Pint said. "At the same time that we talk to alloy manufacturers, we try to interest potential customers and end users in making components out of large heats of AFA steel."

An ideal initial application for AFA steel is heat exchangers, or recuperators, for gas-fired turbines designed to produce electricity. ORNL has worked for 15 years to identify or develop the best affordable alloys for recuperators to improve the efficiency of small (30 kW) to midsize (5 MW) turbines for producing stationary power. An example is Solar Turbines' 4.5 MW Mercury 50 turbine, which was developed under a DOE program and is now one of the company's best-selling engines.

The hot turbine exhaust gas flows past one side of the recuperator steel wall, enabling heat recovery from the gas to air from the compressor flowing along the other side. Owing to the preheated air entering the combustor, less natural gas is burned to spin the turbine. The large pressure differential between the exhaust and compressor air creates a stress that requires excellent creep strength in the thin steel wall.

Pint's research at ORNL showed that conventional type 347 stainless steel, used for decades in recuperators, lacked corrosion resistance to water vapor in the exhaust gas at temperatures above 600°C. Therefore, developers of the current generation of higher efficiency turbines, which operate at higher temperatures, selected austenitic steels high in nickel (alloys 625 and HR120). However, these corrosion-resistant alloys cost about 3 to 5 times as much as type 347 stainless steel. By developing AFA steel, ORNL researchers attained the goal of discovering a less expensive, highly corrosion- and creep-resistant, high-temperature alloy.

ORNL has one CRADA with Solar Turbines and recently completed a CRADA with Capstone Turbine Corporation, where AFA specimens were exposed for 6,000 hours in one of Capstone's 65 kW microturbines. Both companies are considering use of AFA steel for recuperators because of its good creep strength and superior corrosion resistance.

So far Carpenter Technologies has made 25 and 400 lb trial heats of AFA and recently made a 10,000 lb production heat. This material will be used to manufacture AFA steel foil sheet with a thickness of approximately 100 microns (four-thousandths of an inch). The turbine companies will turn the AFA foil into folded steel for use in recuperator components. The thin corrugated steel is expected to outlast even the nickel-based alloys.

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Sponsor: DOE EERE Industrial Technologies Program

Trial scale AFA alloy plates

Processed slab of AFA alloy from Carpenter Technology Corporation's 10,000 lb trial production heat. This material will be used to produce AFA foil and tube forms for end user evaluation.

50-Year-Old ORNL Building Made Highly Energy Efficient

Building 3114 before the energy-efficiency retrofit.

Building 3114 after the retrofit. Parked next to the building is a fuel-efficient Toyota Prius Hybrid car.

A 50-year-old building at ORNL has been transformed into a state-of-the art, energy-efficient research facility. The heat flowing into the building from outside during hot days will be reduced by 75%, according to early test results.

ORNL Building 3114 houses the Distributed Energy Communications and Control Laboratory. ORNL selected the facility as a test site to demonstrate that retrofitting older commercial buildings is a viable, cost-effective option for achieving an immediate reduction in energy consumption and greenhouse gas emissions. ORNL's Energy and Transportation Science Division (ETSD) and the laboratory's Sustainable Campus Initiative funded the project.

Abdi Zaltash of ETSD oversaw and led the monitoring of the project. His supervisor, André Desjarlais, ETSD's group leader for Building Envelopes Research, established the minimum thermal (R-value) requirements and goal of exceeding current code requirements of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). In April 2009 Desjarlais asked consultant Bob Scichili to assemble a project team. He selected Paramount Metal Systems, a design-build firm based in Little Rock, Arkansas, for its ability to do quality designs and contract with suppliers considered the best in the industry. The ORNL team used a solutions-oriented, science-based approach and rigorously analyzed every building product before supporting Paramount's choice of suppliers.

"For ORNL's Sustainable Campus Initiative, we are trying to make our buildings more sustainable by reducing their energy use," Zaltash said. "Building 3114, which was constructed in the 1960s, is an old metal building with a sloped roof that is attached to a masonry building with a flat roof."

The annual utility bill for the nation's 4.8 million commercial buildings is $155 billion. According to the Environmental Protection Agency's ENERGY STAR Challenge, improving the energy efficiency of U.S. commercial and industrial buildings by 10% would eliminate greenhouse gas emissions equal to those of about 30 million vehicles.

Paramount chose Roof Hugger for its purlin system (horizontal board that lies across the rafters at right angles, supports the roofing material, and increases the roof's structural strength); Custom-Bilt Metals, for its reflective metal roofing and wall panels; and Dow Building Solutions, for the company's high-quality thermal insulation to reduce heat flow and losses.

Paramount had to deal with the building's many transitions and penetrations resulting from the attachment of the block masonry building to the metal structure and the need to use various types of equipment and instrumentation inside and outside the building for research. Paramount redesigned the project to ensure that all thermal requirements were met.

Paramount installed Dow's top-of-the-line thermal insulation and an air barrier to raise the comfort level in the interior. Dow's insulating boards, foam insulation, and insulating foam sealant and adhesive have been key factors in the attainment of the project's energy efficiency goals. The R-50 insulation on the roof and the R-30 insulation on the walls have been instrumental in the building's amazing heat flow reductions.

Zaltash led a team that measured heat flow after the retrofit and compared the data with that taken before the project began. The team measured the temperatures inside, outside, and in the sandwich layers. Then the researchers analyzed the differences between the "before" and "after" temperatures and the effects of the retrofit on the latest measurements. "The preliminary data," Zaltash said, "has been indicating about a 75% reduction in the heat flow."

The industrial contractors are pleased with the outcome of the project. Some see the ORNL building as a standard bearer for energy efficiency retrofits of commercial buildings.

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Sponsors: DOE EERE, ORNL Energy and Transportation Science Division and Sustainable Campus Initiative

Vehicle "Fact of the Week" Praised Online

If you like statistics on transportation energy use and manufacturing trends, you might want to add this website to your list of things to do weekly. The Fact of the Week (http://www1.eere.energy.gov/vehiclesandfuels/facts/2011_index.html), developed for DOE's Vehicle Technologies Program by ORNL's Center for Transportation Analysis, contains numerous facts about vehicles and transportation.

A blogger recently wrote: "These little weekly statistical gems are always fascinating to me. The site maintains a listing of previous facts of the week entries dating back to 2003. These archives are a treasure trove of interesting information."

Here are some excerpts:

"Though there has been greater use of lightweight materials, the overall material weight in light vehicles has increased by 376 lbs—from 3,694 pounds in 1995 to 4,070 pounds in 2008."

"The expenditure for a new car as a percentage of annual median family earnings reached its peak in 1993 at more than 45%; in 2009 it declined to its lowest point at just 30%."

"In 1950, the majority of the vehicles were produced in the U.S. and Western Europe. In 2009, Japan, China, and other countries around the world produced about two-thirds of the vehicles. The U.S. share of world vehicle production declined to 9.5% in 2009."

"Highway vehicles were responsible for 80.7% of all transportation energy use in 2008."

"For 2009, Michigan retained its lead position as the top producing state for both cars and trucks. Ohio and Kentucky were the only other states to place in the top 5 for both cars and trucks. Missouri was the second largest producer of trucks for that year."

The ORNL team that produces the "Fact of the Week" includes Stacy Davis, Susan Diegel, and Bob Boundy, all of ORNL's Energy and Transportation Science Division.

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Sponsor: DOE EERE Vehicle Technologies Program

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Continued from page 1

ORNL is also a partner in the first U.S.-China CERC to be established, which is focused on advancing technologies for more efficient clean vehicles. The University of Michigan leads the Clean Vehicles Consortium, which includes core members Ohio State University, MIT, the Sandia National Laboratories, the Joint BioEnergy Institute, and several Chinese universities.

Other members of the consortium include General Motors, Ford Motor Company, Toyota, Chrysler, Cummins, Fraunhofer, MAGNET, A123, American Electric Power, First Energy, and the Transportation Research Center. These members represent many core technologies including battery, engine, and full-vehicle development.

"ORNL will contribute to advanced systems integration; vehicle electrification; batteries and energy storage; lightweight structures; and the characterization, optimization, and combustion of biofuels," said Robert M. Wagner, a manager in ORNL's Energy and Transportation Science Division. "This consortium aligns us with many universities, automakers, and other technology developers." Wagner and other ORNL personnel are members of the executive committee that governs the Clean Vehicles Consortium.

The second CERC to be announced, which involves a U.S. consortium led by West Virginia University, is focusing on developing and testing new carbon capture and storage technologies. The consortium includes two DOE labs—Lawrence Livermore and Los Alamos national laboratories—and industrial partners GE, Duke Energy, and Babcock & Wilcox.

U.S. researchers in the consortium will receive $12.5 million from DOE, matched by at least $25 million in cost-shared research by current U.S. industry partners. Additionally, Chinese research counterparts will contribute an additional $25 million in research efforts over the next 5 years.

The funding for the CERCs from the two nations could total at least $150 million.

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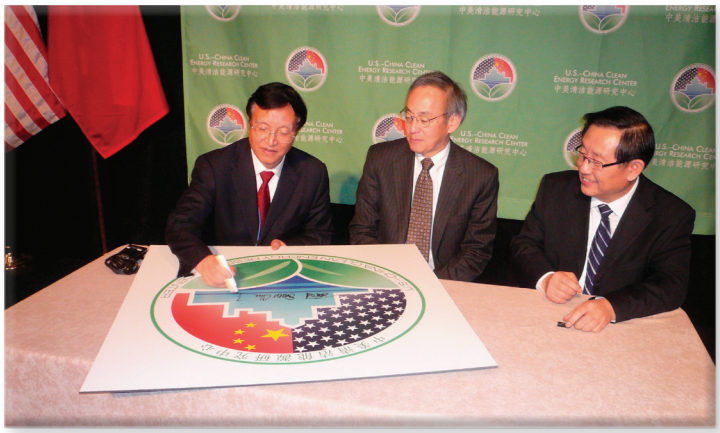
Sponsors: DOE EERE Vehicle Technologies Program and Building Technologies Program, DOE Office of Policy and International Affairs



Wan Gang (left), vice chairman in China's Ministry of Science and Technology; Steven Chu, U.S. Secretary of Energy; and Zhang Guobao, vice chairman in China's National Energy Administration, participate in the signing of the U.S.-China CERC agreement in January 2011.

Will Consumers Buy Plug-in Hybrid Electric Vehicles?

The Obama-Biden Agenda for Energy and the Environment calls for 1 million plug-in hybrid electric vehicles (PHEVs) on American highways by 2015. To reach this goal, consumers must recognize the value offered by a PHEV compared with a less expensive hybrid electric-gasoline vehicle (HEV) and an even cheaper conventional vehicle with an internal combustion engine (ICE).

ORNL researcher Stan Hadley of the Energy and Transportation Science Division (ETSD) and collaborators from other institutions have made these comparisons to determine the "value proposition" for a PHEV. Other ORNL researchers engaged in the study were ETSD's Bob DeVault, David L. Greene, Mitch Olszewski, and Richard L. Smith.

"A plug-in hybrid electric vehicle will bring several advantages to the owner," Hadley said. Compared with a conventional vehicle, a PHEV, such as General Motors' new Chevrolet Volt, has higher fuel economy because it will run at least 40 miles on a battery charge and use petroleum-derived fuel mainly for recharging the battery, reducing the owner's gasoline costs and the national need to import so much foreign oil—a risk to national security.

The study found that by 2030, one PHEV will consume 65% or 75% less gasoline than a comparable HEV or ICE, respectively. A PHEV substituted for an equivalent ICE or HEV will avoid the consumption of 7.25 or 4.25 barrels of imported oil each year, respectively, assuming 60% of the nation's oil consumed is imported.

Because it is much less dependent on its gasoline engine, a PHEV discharges considerably less carbon dioxide into the air than does a conventional vehicle, but its total carbon discharges based on the source of its electricity could be comparable to those of an efficient HEV. Convenient recharging capabilities are being made available for the batteries of PHEVs at home, at federal facilities, and at office parks. The electricity used to charge the batteries will come mainly from natural gas or coal, but increased demand and government policies will encourage the use of other technologies as well.

A plug-in hybrid electric vehicle

For added value, a PHEV in the garage or carport could also be an emergency power source for the house. "Some people will spend a few thousand dollars for an emergency generator for their homes," Hadley said. "Other people ready to buy a car might spend those dollars to cover the higher cost of a PHEV to get an emergency generator in case of a lengthy electrical outage."

The high initial cost of PHEVs presents a major market barrier to their widespread commercialization and adoption by consumers. "It may take a number of years for the lower fuel and maintenance costs to offset the higher upfront cost," Hadley noted. "However, over ten years some experts project that the net ownership cost would be 8 to 10% lower than that of a comparable conventional vehicle and be highly cost competitive with a comparable HEV."

PHEVs have been suggested as a bidirectional electricity technology to improve the reliability and power quality of the electric grid. While PHEV batteries are being recharged by the grid at parking-lot and home-garage charging stations, utilities would like to tap the batteries to draw real and reactive power when needed. This approach could help utilities postpone the construction of new capacity, use the transmission system more efficiently, and improve the quality of power to consumers.

What is the value to a PHEV owner of utility use of the battery? "The utility might pay you directly for the power it draws from your battery," Hadley said. "Another possibility is that the utility might lease the battery to you for a monthly cost. That way you don't have to pay the initial cost of the battery, which is estimated at around $3,000 by 2030. Or, when your car reaches its end of life, the utility might purchase the battery for use at substations or for storage of excess electricity generated by wind turbines and solar arrays."

Hadley has been involved in two phases of a study of "the PHEV value proposition." During Phase 1, which ended in January 2009, SENTECH, Inc., ORNL, General Electric, the Electric Power Research Institute, and the Center for Automotive Research at Ohio State University conducted a study of the benefits, barriers, opportunities, and challenges of grid-connected PHEVs. The purpose of the study was to establish potential value

propositions that could lead to commercially viable PHEVs. During the study, business scenarios were developed based on economic advantages that either increase the consumer value or reduce the consumer cost of PHEVs. The technical and market barriers for these scenarios were identified along with the infrastructure and technologies needed to make PHEVs more attractive to consumers.

The team's case study based in southern California concluded that PHEVs could become commercially viable. The chief reason: the reduced operating and maintenance costs accrued over a PHEV's 10-year lifetime were projected to outweigh the initial vehicle price premium, resulting in significant net cost savings over both conventional ICE vehicles and HEVs. PHEVs in southern California also appeared to reduce greenhouse gas emissions by one-third relative to conventional vehicles.

In June 2010, the Phase 2 study was completed by SENTECH, ORNL, the Center for Automotive Research, and Taratec Corporation. The project team investigated how PHEVs might compete in the coal-heavy Ohio-Michigan region. The team performed sensitivity analyses to determine the effects of varying fuel prices, commuting times, and other input parameters. The team assumed that between now and 2030 a carbon tax will be levied and hybrid and conventional vehicles will improve over time in fuel efficiency, but that the cost of gasoline will soar, vehicle weights will decrease by 30%, and E-85 (15% gasoline,85% ethanol) and other biofuels will be used more.

The team members assumed that increased ownership of PHEVs will drive down the battery cost, from as high as $20,000 currently to as low as $3,000. They also factored in the hidden cost of the capital and installation costs of a home-based charging station, which can be as high as $2,000 now.

"In another case study we looked at the Ohio-Michigan market because most of its electricity comes from coal-burning power plants," Hadley said. "Electricity is cheaper, but the carbon emissions are worse. At night, when lots of PHEVs are using the grid to recharge their batteries, extra power demands will be met by greater use of coal-fired power plants. If there is a carbon tax, power rates will increase significantly in this region."

The study found that by 2030 a typical PHEV will use 18% to 22% less energy than a comparable ICE, but 8% to 13% more than a comparable HEV, assuming a 70/30 split of E-10 and E-85 ethanol-gasoline use that year. Also, a PHEV (and the energy sources that charge its battery) will emit 10% less carbon dioxide than equivalent ICEs in southern California. However, assuming the same ethanol-gasoline split, a PHEV (and the energy sources that charge its battery) will emit 13% more carbon dioxide than an equivalent ICE in the Ohio-Michigan region, where the energy mix has been dominated by coal power.

"If all PHEVs could operate in regions where electricity comes from a high percentage of no-carbon or low-carbon energy sources, such as renewable, nuclear, and natural gas, the long-term environmental impacts of PHEVs would be greatly improved," Hadley said.

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Evaluating Border-crossing Power-line Proposals

On October 27, 2010, state and local leaders in Montana, including two U.S. senators and the governor, held a "groundbreaking" ceremony for the construction of the first transmission power line that will cross the U.S. border from Montana and enable much-needed electrical energy to flow between the United States and the Canadian province of Alberta. The construction of this first Montana-to-Alberta transmission line was recently approved after careful evaluation of the benefits and risks to people and the environment of constructing and operating the line.

The Montana-Alberta Tie Line (MATL) project will result in a 214-mile, 230-kV transmission line that will interconnect the electricity markets of Alberta and Montana. The MATL line will run from a substation outside of Lethbridge, Alberta, to one near Great Falls, Montana. The line will ensure more reliable supplies of electricity in both countries. Both Montanans and Albertans will benefit because they will be less vulnerable to power outages.

For many years the United States has exported and imported electricity over transmission lines supported by tall lattice towers or poles. Power has been both exported to and imported from Canada and Mexico. Several utilities have applied to the U.S. government for permission to build additional transmission lines across the border.

Steel lattice towers in a transmission corridor.

Marti Salk and Ellen Smith, researchers with the Human Health Risk and Environmental Analysis Group in ORNL's Environmental Sciences Division, have been receiving funds from DOE's Office of Electricity Delivery and Energy Reliability (OE) since 2005 because of their OE-recognized expertise in environmental analysis. Their task has involved reviewing National Environmental Policy Act (NEPA) documents for trans-border transmission lines—both environmental assessment (EA) and environmental impact statement (EIS) documents. "Our review role has been to determine whether the analysis was done correctly and whether the results make sense," Smith said.

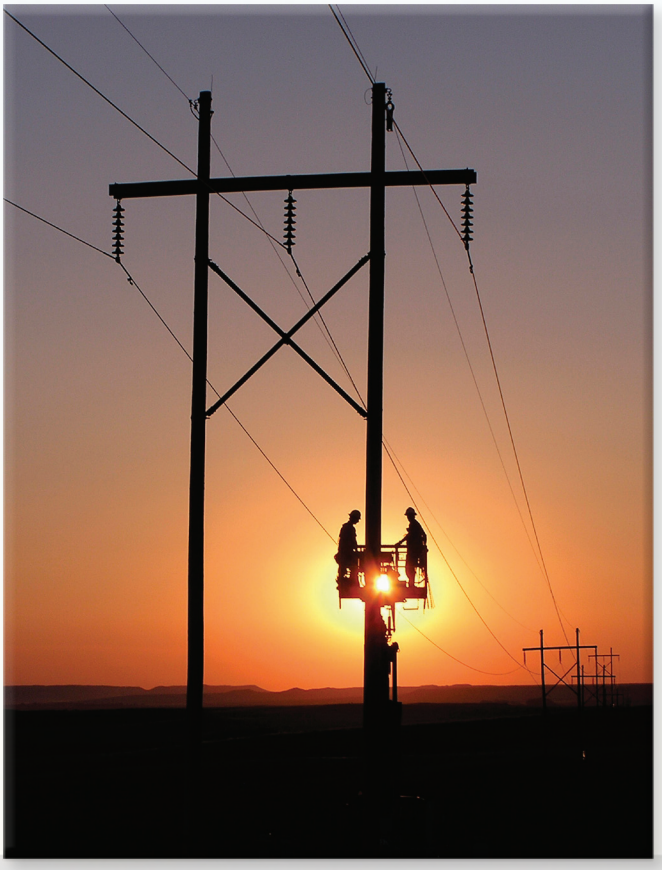
In 1951 President Truman issued an executive order that requires a presidential permit to build transmission lines or transmit electricity across the U.S. border. OE is responsible for making decisions on presidential permits. Before issuing a permit, DOE must comply with NEPA by preparing an EA or EIS analyzing the possible beneficial and adverse environmental and socioeconomic effects of the proposal to ensure that these factors are considered in DOE's decision making, along with electrical reliability and other factors.

For years power has flowed between Washington and British Columbia, Canada, and between the eastern states and eastern provinces, without major concerns about impacts. But the proposed MATL and several lines across the Mexican border have been controversial. MATL was proposed to carry power from wind turbines to be built in Montana. Montanans were concerned that wind turbines have adverse effects. They can spoil people's views of the Rocky Mountains, and the spinning blades can kill migratory birds.

An even bigger issue than wind turbines was the concern of Montana farmers who use huge combines to harvest, cut, and thresh wheat. "No farmer likes operating a combine around transmission line poles erected in vast wheat fields," Smith said. "They are also concerned about running combines under transmission lines." Electrical safety standards dictate a minimum height for transmission lines that ensures safety for the tallest "street" vehicle, which is 14 ft. but at 21 ft. the typical combine is 50% taller, requiring that lines be farther from the ground.

Smith and Salk worked with the state of Montana, which has its own NEPA-like process, as well as OE and TetraTech, the consultant to the Canadian company that finally won approval to build the MATL transmission line. The EIS was published in 2008. "The biggest issues were political—how to weigh the benefits and costs apportioned on both sides of the border," said Smith. Nevertheless, all parties came to an agreement, and the line will be built.

The first NEPA document that Smith and Salk reviewed focused on the 2004 proposal of Tucson Electric Power to construct a second transmission line from near Tucson, Arizona, to the border city of Nogales, Arizona, and across the Mexican border. That line would provide a backup to Nogales' only power line, and it would allow importation of power from Mexico. The transmission line would run through a national forest in Arizona. The EIS examined land-use impacts; ecological effects, such as the impacts of the transmission corridor on the habitats of the jaguar and other endangered wildlife; concerns about the possible health effects of electromagnetic fields from tower-supported transmission lines and about the lines' unattractive appearance; and the socioeconomic impacts of the transmission corridor, which provided illegal migrants from Mexico with an easier path to follow through the rugged mountainous and heavily wooded terrain in the border area.



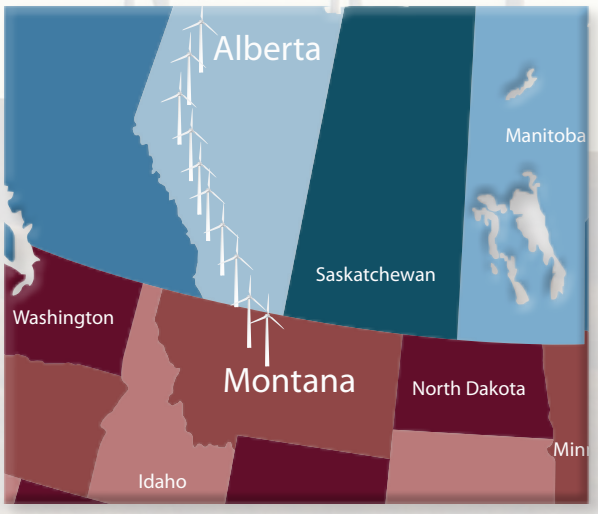
Wooden poles are also used to support electrical transmission lines.

"Our role was to work with OE and the Forest Service on evaluating the issues, defining how the environmental analysis should be structured, and reviewing the work of the consultants to the applicant in preparing the EIS," Smith explained. The EIS also had to determine, under the "environmental justice" Executive order issued during the Clinton Administration, whether transmission lines and towers would adversely affect a minority or low-income community. For example, would the line traverse a mountain considered sacred to the Native American nation of Tohono O'odham?

Another concern is whether a transmission line along a road through the wild part of the national forest would mar the recreational experience of travelers. From a visual standpoint, is it better to locate transmission poles or towers close to the road or off in the distance? Another adverse recreational effect is "corona," a crackling noise resulting from electrical transmission in high humidity. Although the final EIS was completed in 2005, no Presidential permit has been issued. Smith and Salk speculate that if the line is built, its route will be a compromise choice designed to resolve many of the concerns expressed by the Forest Service, landowners, conservation groups, and other interests.

Analysis under NEPA is limited to impacts in the United States, including impacts that result from sources in the border country. Consider the Imperial-Mexicali line over which Mexico exports power to Southern California. Although an EA prepared to comply with NEPA found no significant environmental impacts, environmental groups took DOE to court because they believed that operation of the Mexican gas-turbine power plant would not have been allowed legally in California. The court decided that the EA was inadequate. DOE then prepared an EIS, a more extensive NEPA document that evaluated, among other issues, whether the power plant's use of cooling water from the river flowing north to California adversely affected the quality and availability of river water on the U.S. side.

As North America continues to expand and modernize its electric transmission grid and seeks new sources of electricity, more cross-border transmission lines continue to be proposed, requiring more environmental review in EIS or EA documents. Recently Salk and Smith have consulted with OE regarding ongoing environmental impact statements for controversial lines that would bring wind power from Mexico to Southern California and hydroelectric power from Quebec to New York City. As Salk notes, "Americans are eager to have more power generated from renewable sources, but we've seen that people are concerned about the environmental impacts of the transmission lines that must be built to deliver that power."



The Montana-Alberta Tie Line will run 214 miles between a substation outside of Lethbridge, Alberta, and one near Great Falls, Montana. The line will ensure more reliable supplies of electricity in both countries. Both Montanans and Albertans will benefit because they will be less vulnerable to power outages.

Background image: Wind turbines similar to these will be erected to transmit electricity from Montana to Canada.

Increasing the Paper Industry's Energy Efficiency

One way to make the paper industry more energy efficient is to replace the paper mill recovery boiler with a black liquor gasifier. This approach presents some materials endurance issues that ORNL researchers are helping to resolve.

Black liquor is an aqueous solution consisting of lignin and hemicelluloses (the organic material in trees) as well as spent pulping chemicals in the form of sodium carbonate and sodium sulfate. The paper mill's recovery boiler is a key component in the system to regenerate sodium hydroxide and sodium sulfide, the active ingredients in kraft pulping liquor. This "white liquor" breaks the bonds between lignin and cellulose in wood chips to produce pure cellulose fibers for making paper. In the recovery boiler, the organic components of black liquor are burned to produce heat for generating steam, and the sodium sulfate is reduced to sodium sulfide as one step in the recovery of the pulping liquor.

The steam generated in the recovery boiler is used both in the papermaking process and in the generation of electricity. Paper mills typically generate more than half the electricity they require using steam produced in the recovery boiler and steam generated in other boilers burning wood waste, bark, and other material.

"A gasifier can recover more energy from black liquor than can a recovery boiler," said Jim Keiser, a researcher with ORNL's Materials Science and Technology Division (MSTD). "The gasifier also enables the recovery and recycling of pulping chemicals."

Keiser, MSTD's James Hemrick, and the University of Tennessee's Roberta Meisner have used funding from DOE, Weyerhaeuser Company, and the Swedish company Chemrec AB to identify mechanisms degrading the refractory lining of the black liquor gasifier developed by Chemrec. In the gasification process, water is evaporated and the organic components are gasified, leaving the spent pulping chemicals in the form of molten sodium salts.

A foreign research organization had recommended a refractory material for the Chemrec gasifier that was installed and operated at a Weyerhaeuser paper mill in New Bern, North Carolina. Because of wastage of the refractory lining, the gasifier initially had to be shut down after 3 to 4 months of operation for repairs to be made to the refractory lining.

Chemrec initially used a mullite, or alumino-silicate ceramic, as the primary high-temperature refractory lining. However, the mullite held up less than a year, the minimum needed to bridge 2 planned maintenance stops. Chemrec substituted a fusion-cast alumina-based material that lasted a year but had deficiencies.

After extensive field and laboratory studies, the ORNL team found that a fusion-cast aluminum oxide–magnesium oxide spinel should last as long as a year as a high-temperature lining for vessels of molten salt. Eventually, it was determined that the magnesia-alumina spinel would survive for at least two years as the primary high-temperature refractory.

However, the secondary, or backup, lining posed a challenge when refractory replacement was scheduled for every two years. The issues concerned both the selected backup material and Chemrec's ongoing design of the overall lining system. This problem with the backup lining prompted the ORNL team to conduct studies to find better candidates. Working with a supplier, the team discovered that improved compositions of a calcium oxide–aluminum oxide ceramic should last two years as a refractory backup lining. The ORNL researchers tested different compositions of the ceramic by immersing samples in molten sodium salts and examining the exposed refractories with x-ray diffraction and advanced microscopy techniques to determine how much they had corroded. Then they recommended the composition that was most resistant to corrosion for the backup lining.

Identifying the best material can prevent frequent shutdowns.

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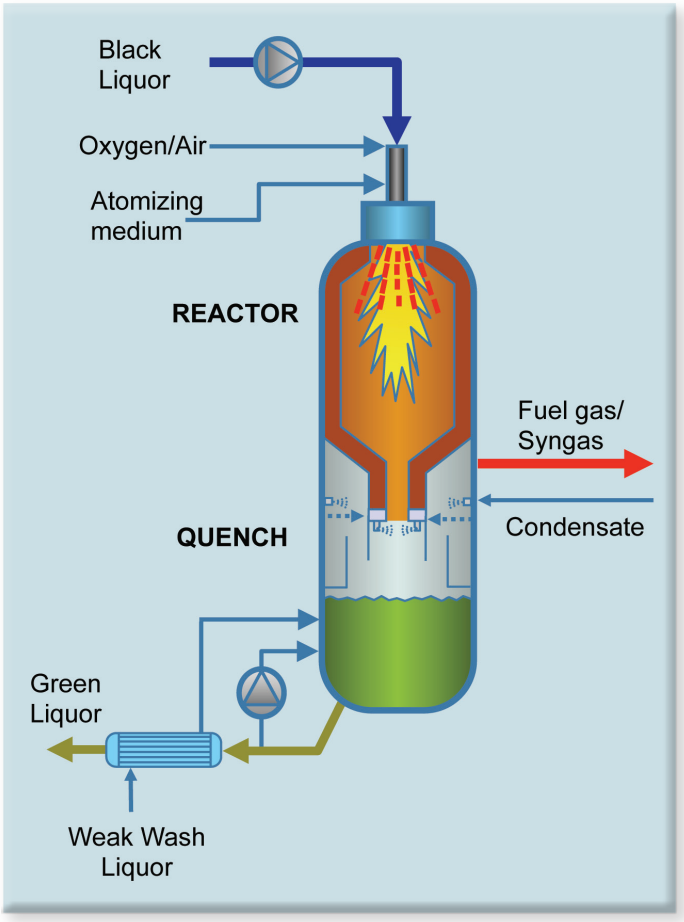
Sponsor: DOE EERE Industrial Technologies Program



This schematic illustrates the high-temperature, slagging gasifier developed by Chemrec AB. The low-pressure version has been in use at a paper mill in New Bern, North Carolina, for almost 50,000 operating hours. Black liquor, steam, and air are injected at the top of the gasifier. The product gas is removed just below the level of the reactor, which has a two-layer refractory brick lining. The smelt is cooled and then dissolved in water at the bottom of the vessel. A high-pressure, oxygen-blown version of this gasifier has been in operation in Piteå, Sweden, since 2005.

Honors and Awards

Amit Goyal

R&D Magazine, a leading technology publication that manages the annual R&D 100 Awards competition, has named **Amit Goyal**, a researcher in ORNL's Materials Science and Technology Division (MSTD), as the magazine's ***Innovator of the Year***. Goyal's pioneering research has had a profound impact on the science and technology transfer of high-temperature superconductivity.

Abdolreza Zaltash, a researcher in ORNL's Energy and Transportation Science Division, has been named a ***Fellow of the American Society of Mechanical Engineers***. He was recognized for his research contributions in heat-activated technologies and cooling, heating, and power production.

Abdolreza Zaltash

Zhili Feng, an MSTD researcher, will receive the ***Distinguished Alumni Award from Ohio State University's Materials Science and Engineering Department***. Feng, who received his Ph.D. degree from Ohio State, was recognized for his work related to computational weld mechanics and materials, computational simulations of welding processes, and applications of neutron and synchrotron scattering for materials research.

Zhili Feng

RABiTS Photovoltaic Technology has won a ***Southeast Regional Federal Laboratory Consortium Award***. The award honored Flexible Thin-Film Solar Photovoltaics (deposited by DOE's National Renewable Energy Laboratory) on Rolling Assisted Biaxially Textured Substrates (RABiTS), developed by ORNL. RABiTS is a flexible, textured metal foil originally made to form a platform for high-temperature superconducting materials. The winning ORNL team includes **Parans Paranthaman, Dominic Lee, Frank Damiano,** and **Glenn Kline**. Ampulse is the company working on commercializing the combined DOE technologies to produce flexible, highly efficient, low-cost, and durable photovoltaic materials for commercial products.

ORNL has received a 2010 ***Federal Energy and Water Management Award*** and a 2010 ***Department of Energy Management Award*** in recognition of its Sustainable Campus Initiative. ORNL was recognized for its ***outstanding achievements in energy, water, and fleet management*** by the Federal Interagency Energy Policy Committee and DOE's Federal Energy Management Program.

Efficient new buildings such as the Joint Institute for Biological Sciences and ORNL's aesthetic efforts received national recognition.

Wireless Sensors Make ORNL Steam Lines More Efficient

ORNL could save up to $675,000 annually if steam trap upgrades to its 12 miles of steam lines also include the widespread installation of specific wireless sensors. ORNL personnel are developing and installing a distributed wireless sensors network for multiple steam trap locations, and researchers are evaluating the sensors' ability to accurately measure steam temperatures and flow rates, as well as any changes in the steam traps. The measurements will enable the sensors to locate energy-sapping steam leaks.

The purpose of the prototypic wireless sensors is to demonstrate the feasibility of an early warning system for imminent steam trap failures. Each sensor is designed to detect acoustic signatures and a rapid temperature rise from sudden leaks of hot steam and to send a radio signal that indicates the location of a potentially failing steam trap.

ORNL pipelines are outfitted with 1,600 steam traps, which normally open slightly to discharge condensed steam, or water, with only small energy losses. A tiny amount of flash steam also escapes from a properly functioning steam trap when the pressure is permitted to drop. Considerable heat energy in the steam is wasted if a trap fails and the failure is not detected and repaired in a timely manner. Manual inspections are time-consuming, costly, and sometimes dangerous, so wireless sensors are an attractive solution for detecting and communicating leakage problems.

According to a 2006 DOE Federal Energy Management Program Technology Alert, steam trap failures are a major waste of energy at industrial sites. "Approximately 20 percent of the steam leaving a central boiler plant is lost via leaking traps in typical space heating systems without proactive assessment programs," the report states.

"Early detection of steam leaks is the key to minimizing the losses and maximizing the cost savings," said Wayne Parker of ORNL's Utilities Division. Others contributing to the project include Teja Kuruganti, Glenn Allgood, Joe Lake, Seddik Djouadi, Wayne Manges, Robert Baugh, and Teresa Baer.

Background image: Steam lines at ORNL

Included in This Issue:

- ORNL Involved in 2 U.S.-China Clean Energy Research Centers 1
- 45% Efficiency Achieved in Diesel Engine Tests 2
- ORNL Steel Produced for Gas Turbine Tests 3
- 50-Year-Old Building Made Highly Energy Efficient 4
- Vehicle "Fact of the Week" 5
- Will Consumers Buy Plug-in Hybrid Electric Vehicles? 6
- Evaluating Border-crossing Power-Line Proposals 8
- Increasing the Paper Industry's Energy Efficiency 10
- Honors and Awards 11
- Wireless Sensors Make ORNL Steam Lines More Efficient 11
- News Briefs 12

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News Briefs

ZEBRAlliance Houses Open as Monitored Energy-Efficiency Labs

A ribbon-cutting ceremony held Sept. 20, 2010, celebrated the opening of all four homes as laboratories in the first ZEBRAlliance project, a major milestone. A public-private partnership founded by ORNL and Schaad Companies, ZEBRAlliance is both a research project and a multi-faceted energy-efficiency education campaign. The four houses, located in the Crossroads at Wolf Creek subdivision in Oak Ridge, use 55%–60% less energy than conventional houses yet maintain similar amenities. ORNL Director Thom Mason, who was present at the ceremony, said, "These homes are a great example of what can be done when we partner with industry to provide scientific solutions to real problems."

Ribbon-cutting ceremony for energy-efficient houses.

KUB Trucks Wired for Data Acquisition

One of the KUB vehicles in the MTDC effort

ORNL researchers led by Gary Capps in the Energy and Transportation Science Division are carrying out a vehicle monitoring study that could guide the transformation of energy-intensive transit buses and utility trucks into energy-efficient vehicles. They have installed data acquisition and wireless communication systems on several heavy vehicles owned by the Knoxville Utilities Board (KUB) to enable closer observations of machine performance in real time. Called the Medium-Truck Duty Cycle project, the study is designed to provide the first quantitative profile of the behavior of medium-sized trucks during driving. The more thorough understanding of vehicle performance could lead to recommendations for more-effective fuel efficiency improvements in medium trucks.