Science & Technology HIGHLIGHTS

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Bioenergy: A Renewed Focus on Renewable Resources

In August 1999, President Bill Clinton issued an executive order to "further the development of a comprehensive national strategy … to make biobased products and bioenergy cost competitive in national and international markets." The order outlined a goal to triple U.S. use of biobased products and bioenergy by 2010. In June 2000, Congress passed and President Clinton signed the Agricultural Risk Protection Act of 2000, which provides for establishment of an interagency R&D program on the use of biomass to produce energy, fuels, and other industrial products.

"Biomass" can be trees, agricultural crops or waste, forestry residue, municipal waste, animal waste, fibers, grasses—anything organic in nature and available on a recurring or renewable basis. "Biobased industrial products" encompasses liquid and gaseous fuels, chemicals, electric power, heat, and building materials.

Achieving the President's goal would generate billions of dollars of new income for farmers and create 50,000 new jobs in small, rural processing plants. Up to 130,000 jobs would be created in bioenergy industries. Bioenergy would generate the equivalent of 348 million barrels of oil each year—about 158 supertankers—and lower carbon emissions by 100 million metric tons of carbon equivalent, comparable to taking 70 million cars off the road. Other benefits are likely; the plants that look most useful for biomass production tend to be deep-rooted and could help control erosion and filter chemicals from water runoff.

The Departments of Energy and Agriculture have lead roles in shaping and carrying out the R&D program. For DOE, ORNL and the National Renewable Energy Laboratory support the Technical Advisory Committee and the Biomass R&D Board established by the Act, and coordinate information dissemination and outreach. The two labs also will analyze technology gaps and help develop strategic plans and technology roadmaps, among other activities.

ORNL researcher Janet Cushman examines specimens of switchgrass, a promising bioenergy crop that could produce biomass for energy while helping control erosion and protect water quality.

Both ORNL and NREL have successful track records in biomass-related R&D. ORNL focuses on integrated economic and environmental analysis, as well as research to improve the yields, quality, and sustainability of energy crops. NREL focuses on converting biomass—from both energy crops and waste—to ethanol, other liquid fuels, and electricity. Both labs work on converting biomass to commodity chemicals and other industrial products.

In 1998, ORNL and NREL were part of a team that developed an award-winning process to produce succinic acid from corn [see *Science & Technology Highlights* **1** (1999), p. 4].

This issue highlights some current ORNL R&D on bioenergy-related topics. An economic analysis demonstrates that bioenergy crops can raise farm income without disrupting traditional crop prices. We also look at efforts to use bioenergy crops to filter runoff from commercial livestock operations. We'll review outcomes from a recent conference on animal waste management, and take a quick look at the agriculture "Industry of the Future" vision and technology roadmap.

BTC Helps Solve the Mystery of Crumbling Buildings in Seattle

Plagued by failures of recently constructed buildings, Seattle officials have asked ORNL's Buildings Technology Center (BTC) for help. Anecdotal evidence suggests a connection between premature deterioration of buildings due to moisture accumulation in ultra-humid Seattle, and the increase in building tightness and insulation levels over the years to improve energy efficiency.

The costs of the problem are dramatic. In 1998, an informal survey of residential buildings in the metro area by Seattle's Construction Codes Advisory Board found about 70% of structures surveyed reported moisture damage. The estimated repair cost for the buildings surveyed is nearly $70 million; the cost of repairing all of Seattle's building stock could reach $1 billion. And the problem is not limited to Seattle: Atlanta, Wilmington, North Carolina, and other high-humidity areas also report growing problems from moisture damage to buildings.

Moisture leakage into this stucco wall system has led to severe rotting of this six-year-old building in Seattle.

Why are energy efficiency researchers concerned? There are several reasons:

- If there is a cause-and-effect relationship between tougher standards for building tightness and moisture intrusion, the standards may be relaxed and the efficiency gains made over the last decade or so may disappear. Anecdotal information persists that air-tightness controls—which may account for 30–50% of the energy efficiency gains in buildings—are responsible for moisture-induced damage.
- As moisture accumulates within the envelope, the apparent thermal conductivity of building materials increases substantially. The result is higher energy costs.

Thermal conductivity increases as moisture accumulates in the building envelope: up to 3 times for polystyrene foam insulation, 4 times for high-density glass fiber insulation, 2.3 times for concrete, and 2 times for red brick.

The BTC's Hygrothermal Properties Laboratory will be used to measure the moisture properties of materials typically used in wall systems in Seattle.

- Localized evaporation and condensation in building envelope components can increase energy transfer across components by 5% to 150% compared with transfer under dry conditions.

The BTC is working with Seattle to develop building envelope designs and control strategies that achieve both energy efficiency and moisture control. The project is under way with input from Washington State University Cooperative Extension Energy Program, Seattle's Construction Codes Advisory Board, consultants, and architects. The initial phase will subject typical western Washington building envelopes to a Seattle-like climate to assess sensitivity to moisture transport. It will also compare the relative thermal and hygrothermal performance of older and newer building enclosures. Extensive field investigations and advanced hygrothermal modeling will be performed. This phase is expected to provide preliminary scientific evidence to support or refute widely held beliefs regarding moisture differences between older and newer structures. In addition, this phase should determine the effects of state building, ventilation, indoor air quality, and energy codes on hygrothermal performance.

In later phases, manufacturers of construction materials and envelope systems will be invited to participate in defining design guidelines for wall systems for Seattle's climatic conditions. A larger set of hygrothermal influences (air leakage control strategies, drainage strategies, vapor control strategies and thermal strategies) will be analyzed. Field demonstrations will be conducted concurrently to provide a reality check on the design guidelines developed.

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Partnership with Habitat Benefits Homeowners and Researchers

Two new houses in Lenoir City, Tennessee, reflect a continuing partnership between ORNL's Buildings Technology Center and Habitat for Humanity that provides energy-efficient construction for Habitat homeowners and real-world field testing for researchers. The houses were built using innovative energy-saving technologies developed at ORNL. The BTC will monitor energy usage in the houses during the coming year to see how well the technologies perform.

The houses were built using a concrete form wall system that includes light, insulating polystyrene foam blocks interlocked to form the walls and then filled with concrete. The monitoring will help researchers determine how characteristics of the wall system, such as thermal mass and air-tightness, affect the energy performance of the house.

BTC research technician Jerry Atchley examines polystyrene modules of a concrete form wall system used in the Habitat houses.

At the dedication of two Lenoir City Habitat for Humanity dwellings, BTC director Jeff Christian explains energy-efficient building techniques used in the construction.

The effort is a partnership among DOE, Habitat for Humanity of Loudon County, and the Insulating Concrete Forms Association. It is an outgrowth of a 4-year energy efficiency study at the BTC in which more than 100 types of wall systems were tested and analyzed.

Previously, ORNL has developed materials to guide Habitat volunteers through tasks and techniques for building energy-efficient houses and provided assistance in designing energy-efficient houses.

A group of current and retired ORNL employees were among the volunteers who built the homes earlier this year. BTC researchers are working on other energy-efficient wall systems that they hope will be used later in Habitat houses in the same neighborhood. The homes are located in the Harmony Heights subdivision.

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BTC Facility Is an Energy Star

Building 3147, the office building for ORNL's Buildings Technology Center, has been presented the Energy Star rating for buildings that meet energy efficiency standards set by DOE and the Environmental Protection Agency. It is one of two buildings in the state, one of 200 in the country, and one of only 40 government buildings to win the rating.

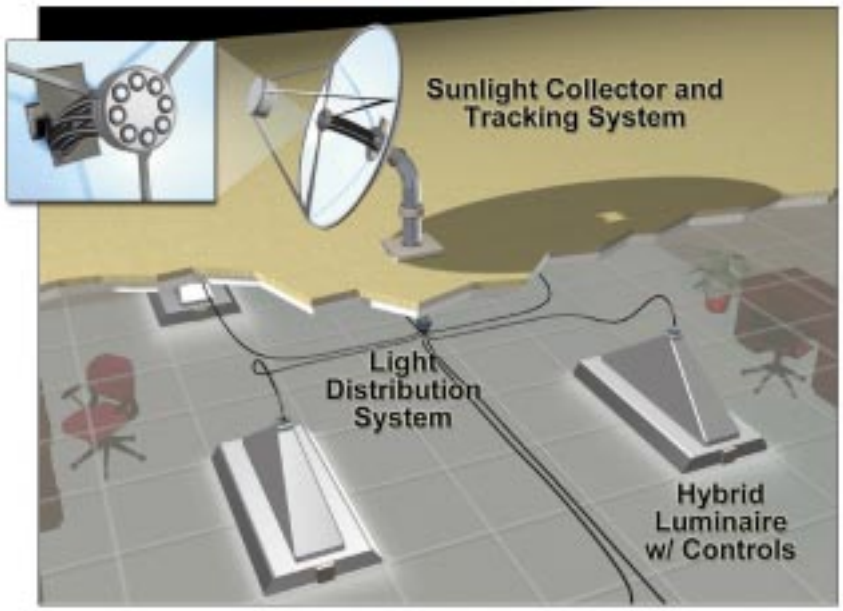
An energy management system was installed during construction of the building in 1985. In 1994, the lighting was converted to high-efficiency lights controlled by occupancy sensors; that move alone reduced the building's energy use by 20%. BTC staff member Terry Sharp oversaw most of the efficiency improvements that led to the rating.

Hybrid Lighting Promises Cool, Efficient Light and More . . .

Research under way at ORNL could lead to entirely new, highly energy-efficient ways of lighting buildings using the power of sunlight. In addition to providing light, the technology would convert sunlight to electricity much more efficiently than conventional solar technologies.

In commercial buildings, lighting consumes more electric energy than any other building end-use. It accounts for more than a third of all electricity consumed for commercial use in the United States. Typically, less than 25% of that energy actually produces light; the rest generates heat that increases the need for air-conditioning. ORNL is developing a system to reduce the energy required for lighting and the air-conditioning loads associated with it, while generating power for other uses—heating or cooling, for example.

The concept, originated by ORNL's Jeff Muhs, separates and uses different portions of sunlight for two applications, interior lighting and distributed power generation. The concept takes advantage of two facts. First, the luminous efficacy *(or light output per unit of energy, expressed as lumens per Watt)* of the visible part of the spectrum is more than double that of electric lamps. Second, photovoltaic cells, especially thermo-photovoltaic cells, are very efficient in converting the infrared portion of the spectrum to electricity.



In a solar lighting and power system, the roof-mounted concentrators collect sunlight and distribute it through the optical fibers (enlargement) to hybrid lighting fixtures in the building's interior. The system also produces electricity for supplemental lighting or other uses.

The system will use roof-mounted concentrators to collect and separate the visible and infrared portions of sunlight (see the figure). The visible portion will be distributed through large-diameter optical fibers to hybrid luminaires. (Hybrid luminaires are lighting fixtures that contain both electric lamps and fiber optics for direct sunlight distribution.) When sunlight is plentiful, the fiber optics in the luminaires provide all or most of the light needed in an area. Unlike conventional electric lamps, they produce little heat. During times of little or no sunlight, sensor-controlled electric lamps operate to maintain the desired illumination level.

The remaining "invisible" energy in the sunlight, mostly infrared radiation, is directed to a concentrating thermo-photovoltaic cell that very efficiently converts infrared radiation into electricity. The resulting electric power can be directed to other uses in the building.

Independent cost and performance models suggest the overall affordability of solar energy could be doubled or tripled using this new hybrid approach. The multidisciplinary R&D effort includes several industrial and university partners.

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Shedding New Light on Public Housing

ORNL's Buildings Technology Center is a collaborator in the development of energy-efficient, low-maintenance light fixtures for public housing that also resist vandalism and theft. Installed in public areas of Chicago housing projects, the lights replace incandescent fixtures that could not stand up to the Chicago weather or to vandals, bulb thieves, and criminals who prefer to lurk in the dark. The incandescent fixtures were often broken or stolen within days of installation, and the lack of lighting presented a safety and security hazard for residents.

ORNL staff working with the Chicago Housing Authority learned of the lighting problem and arranged for Auburn University's industrial design department to develop a more robust light fixture as a student design project. The design ultimately chosen is a square fixture of 16-gauge steel with a break-resistant polycarbonate lens. The two 18-watt compact fluorescent bulbs in each box provide 20% more light than the incandescent bulbs and last about 10 times longer. They're also less desirable to thieves.

The lights performed well in field tests, and the Housing Authority has completed the installation of about 200 fixtures in one building. In addition to saving energy and money for the Housing Authority, the new lights will create a safer and more secure environment for public housing residents.

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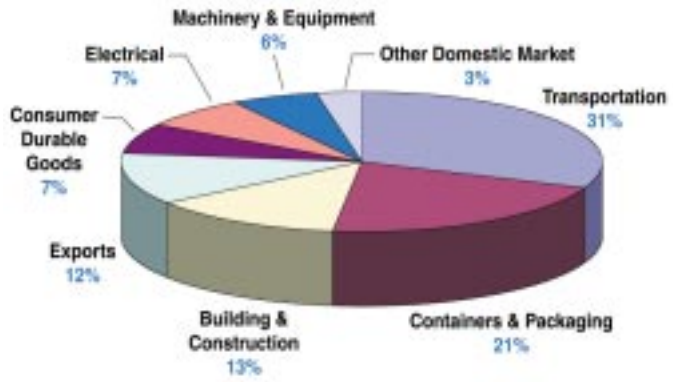
Aluminum Industry Vision: Efficient, Clean, and Competitive

Light in weight, corrosion-resistant, strong, and recyclable, aluminum shows up in all sorts of products, from engine blocks to food wraps. The United States led primary aluminum production in 1960, providing about 41% of the world's aluminum. By 1992, market forces had driven down the U.S. share of world aluminum production to about 21%.



The U.S. aluminum industry shipped over 24 billion pounds of aluminum in 1999 for use in markets vital to the U.S. economy. Source: *Aluminum Facts at a Glance*, The Aluminum Association, Inc., June 2000, www. aluminum.org.

Primary production of aluminum is energy-intensive; energy costs—over $2 billion in 1997—make up almost a third of the cost of primary aluminum production. (Recycling of aluminum, called secondary production, consumes only about 5–8% of the energy used in primary production, but accounts for only about a third of the U.S. aluminum supply.) Reducing energy needs while maintaining or increasing product yield and quality is key to retaining and growing the U.S. share of primary aluminum production.

The industry has worked with DOE and the national laboratories to map science and technology paths that will help the industry achieve its vision of increasing energy efficiency, improving product quality, and lowering pollution and waste from production and manufacturing. ORNL is working with industry, universities, and other national laboratories on several projects that fill technology needs:

- Processes to reduce oxidative melt loss in production of aluminum and alloys
- Modeling of the direct chill casting process, to find ways to reduce stress cracking in ingots
- A way to prevent steam explosions in casting pits (*Science & Technology Highlights* **2**, 1999)
- Identification and optimization of aluminum alloys for semi-solid metalcasting that will save materials and energy, increase yield, and improve quality

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Industry-Wide Performance Targets

Cost and Productivity Targets

Reduce the costs associated with metal production by 25%.
Reduce the cost ratio of aluminum to steel to less than 3-to-1 for auto applications.
Increase the capital productivity of the aluminum industry.
Reduce product costs and product lead times through process reengineering.

Market Targets

Increase aluminum use in auto markets by 40% in 5 years.
Increase aluminum use in non-auto transportation markets.
Increase aluminum use in infrastructure markets by 50%.
Increase aluminum use in building and construction markets.

Environmental Targets

Recycle and treat all types of aluminum wastes.
Increase recyclability of aluminum scrap.
Achieve 80% wrought recycling of autos by 2004.

Energy Targets

Increase the efficiency of the Hall-Heroult cell process to over 97%.
Reduce overall energy intensity of aluminum production.

Health and Safety Targets

Increase the health and safety of workers.

Workforce Targets

Increase the level of training and knowledge of the existing aluminum industry workforce.
Increase the number of qualified scientists and engineers available to the aluminum industry.

Source: *Aluminum Industry Technology Roadmap*, The Aluminum Association, May 1997.

ORNL and Secat Sign Partnership Agreement

ORNL signed a memorandum of understanding with Secat, Inc., of Lexington, Kentucky, on April 28, 2000, to establish a partnership to provide economic, environmental, and energy benefits to the aluminum industry.

Argonne National Laboratory and the Albany Research Center in Albany, Oregon, also signed the agreement.

Secat, Inc., is a newly formed University of Kentucky-affiliated for-profit company that serves as a technical forum for the aluminum industry. Secat has been a user of ORNL's MPLUS national user facility, which is funded by the Office of Industrial Technologies. Programs currently under way with Secat and funded by OIT's aluminum program include research into how to reduce stress cracking in aluminum ingots, and how to reduce oxidative melt loss in aluminum and aluminum alloys.

Vision for U.S. Agriculture: Crop-based Renewable Feedstocks

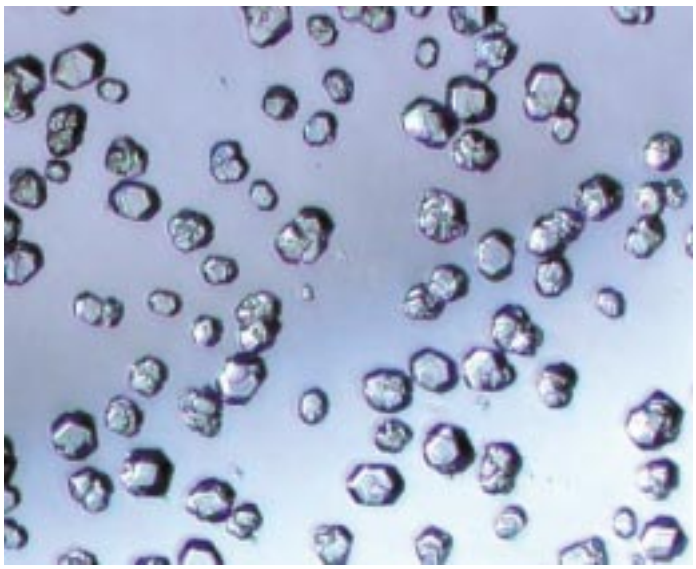
In 1996, the National Corn Growers Association hosted a workshop that eventually led to development of a strategic vision for the plant- and crop-based renewables industry. The agribusiness community envisions a time when these renewables will complement fossil fuel feedstocks to meet the needs for chemicals, materials, and other industrial products.

The document, *Technology Roadmap for Plant/Crop-Based Renewable Resources 2020*, laid out the R&D needed to address technical and market barriers. According to the roadmap, achieving the strategic vision will require progress in four areas:

- plant science, including functional genomics and metabolic pathways
- plant/crop production, including productivity improvement and agronomic practices
- processing, including separations and conversion
- utilization, including infrastructure, distribution systems and impact on rural communities.

ORNL is poised to contribute to this "new" industry through expertise in all four of the major R&D areas:

- The Biofuels Feedstock Development Program selects and engineers grasses and trees for optimum yield and potential use as dedicated "energy crops." In collaboration with a network of partners, including the U.S. Department of Agriculture and universities, BFDP conducts field trials that also address agronomic and harvesting issues. One group is studying the economics of energy crops *(see the following article)*. This on-going program is sponsored by the DOE/EE Office of Transportation Technologies and Office of Power Technologies.
- ORNL has expertise in converting plant-based materials to chemicals using novel enzymes and bioreactors. Under sponsorship of the Chemical Industry of the Future, ORNL was part of an award-winning team that developed a process to convert corn into a cost-effective source of chemicals used to make polymers, fibers, paints, inks, and other industrial and consumer products.
- ORNL will provide bioprocess engineering and testing for a project that seeks to thermostabilize the enzyme glucose isomerase (GI) as a cross-linked enzyme crystal (CLEC®). GI CLEC would allow direct conversion of glucose syrup to 55% fructose syrup at higher temperatures than currently used and eliminate the chromatography step of the current process. GI CLEC will save energy by decreasing the need for evaporation. The dextrose feedstock for the process can also be of lower quality if the GI form offers enhanced organic resistance. The CLEC form will have a long lifetime with the potential for multiple reuse.



Use of these cross-linked enzyme crystals would save energy in fructose processing.

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Where Will Bioenergy Crops Be Most Profitable?

Biomass has the potential to displace fossil fuels used for power, fuel, and production of chemicals. Most of today's efforts to use biomass for power or fuel focus on using forestry wastes or consumer wastes as the primary source of biomass. ORNL researchers envision a future where renewable biomass is a resource so widely used that it becomes an integral part of American farms, grown on agricultural land using practices similar to those used with more traditional crops.

Researchers from ORNL and the University of Tennessee have used an agricultural simulation model to evaluate potential economic impacts of bioenergy crops in the U.S. agricultural sector. The model, POLYSYS, estimates supply, demand, price, and farm income for the major farm crops. The researchers modified it to include bioenergy crops such as switchgrass, hybrid poplars, and willows.

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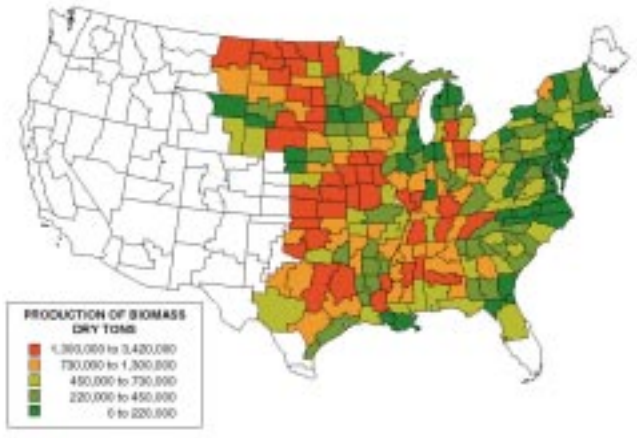

Projection of switchgrass production regions in 2008 (Price = $40/dry ton).

Research Explores Use of Animal Wastes to Fertilize Bioenergy Crops

Seeking to transform an environmental problem into an energy resource, ORNL researchers are helping the states of Maryland and Delaware explore alternatives for dealing with the large quantities of poultry litter (bedding and manure) generated by commercial poultry farmers on the Delmarva peninsula. The objective of this project is to reduce the runoff of nutrients, particularly phosphates, to the Chesapeake Bay as an attempt to reduce periodic outbreaks of the toxic dinoflagellate *Pfiesteria* in the Bay and its tributaries.

The project is examining several options for dealing with the litter. The ORNL researchers have investigated the economics of one alternative, producing woody and grassy biomass in buffer strips between field crops and adjacent waterways. The bioenergy crops intercept excess nutrients and minimize the runoff from poultry litter applied to the field crops, protecting the waterways from degradation.

The study concluded that with cost-sharing through the enhanced Conservation Reserve Program, switchgrass planted in buffer strips could be produced economically at $30 per ton. Willow, a woody crop, would cost $60 to $80 per ton when produced in 100-foot buffer strips. Another field study conducted by ORNL, the Tennessee Valley Authority, and the University of Tennessee at the Ames Plantation validates the role of animal manures as a nutrient for biomass. In that study, cottonwoods grew significantly more when fertilized with swine slurry than with a comparable nitrogen-phosphorous-potassium chemical fertilizer.

Animal wastes are a major cause of nutrient runoff and of degraded water quality, particularly in areas where animals are raised in large feedlots. Using bioenergy crops as nutrient filters and animal wastes as organic fertilizers for the crops could offer multiple economic and environmental benefits for both animal waste management and biomass production. ORNL researchers are beginning to identify specific nutrient requirements of woody and grassy feedstocks that could be supplied with animal manures. They are also examining how these nutrient resources can be applied and managed to enhance biomass productivity, soil quality, and carbon storage in the soil. Developing these relationships can help define the broad-scale compatibility and environmental potential of combining biomass production and animal nutrient management.

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Toward Environmentally Sustainable Animal Farming

Animal farming is vital to the economy and security of the United States, producing low-cost eggs, meat, and milk. An inevitable by-product of the industry is manure, which should be a resource but, through careless disposal, has become an environmental problem instead. The University of Tennessee's Joint Institute for Energy and Environment (sponsored by ORNL, the Tennessee Valley Authority, and UT) recently sponsored a workshop to address how to use farm animal manure to benefit farming and the environment.

As the industry has evolved, production of both food products and manure has become more concentrated and, in many cases, separated from areas where manure could be used to fertilize pastures and fields. In addition, stricter environmental regulations to protect water are cutting profits to producers. Actions are needed to reform the U.S. product marketing system and protect an important contributor to the well-being of the United States.

The workshop report (www.jiee.org) cites a vision of "environmentally sustainable food animal operations that are safe, socially acceptable, and profitable." A primary obstacle to realizing this vision is that producers cannot easily pass on the real cost of environmental compliance to consumers.

Fortunately, there are a number of complementary routes to rectifying some of the problems:

- A more systematic approach to policy, regulation, penalties and incentives
- An improved nutrient recycling system
- The use of value-added, bio-solid and bio-energy products
- Voluntary programs for environmental certification, coupled with environmental labeling and premium prices
- Enhanced assistance programs tailored to farmers and to public education.

Even with offsets for producers' waste disposal costs, most farmers need a more direct approach to paying the real costs. Specifically, consumers should pay realistic prices for products and support government programs that ensure the optimum use of animal wastes. The principal recommendations from the workshop were these:

- Transfer the real costs of environmental compliance to consumers
- Maximize the beneficial use of animal manure and commercial fertilizers to minimize environmental impacts
- Support efforts to move existing technologies into the marketplace and increase funding for new technologies
- Fully fund the proposed bio-solids and bioenergy initiative and the Lugar Bill for research on commercially viable technologies
- Develop a comprehensive Farm and Environment Bill that updates and consolidates regulations to address issues on a national and state level.

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Making Connections at the Distributed Generation Showcase

Many energy experts envision a future in which the current system of central power plants is transformed into a decentralized network offering users an array of centralized and distributed power generation options. This future would provide cleaner and more reliable, efficient, and affordable energy resources. But how do we get there from here? What technical barriers need to be addressed to produce ultra-low-emission, fuel-flexible, and cost-competitive distributed energy technologies? How can the next generation of power equipment be interconnected with the nation's current electricity delivery system?

Ralph Dinwiddie of ORNL's High-Temperature Materials Laboratory tours showcase participants through the HTML facility.

To answer such questions, ORNL hosted a Distributed Generation Showcase in June, in collaboration with the National Renewable Energy Laboratory, DOE's Office of Power Technologies, and numerous industrial partners.

Distributed power is modular electric generation located close to the point of use. It includes environmentally friendly renewable energy technologies such as wind turbines and solar photovoltaic cells, as well as highly efficient fossil-fuel technologies such as gas turbines and fuel cells. Decades of public and private investment in R&D have begun to yield major improvements in the performance of these options, and this emerging portfolio of energy resources is in the early stages of commercial development.

Each technical session at the workshop featured technology updates by a national laboratory speaker and an industrial partner.

- The session on natural gas technologies provided updates on gas turbines, microturbines, and fuel cell technology.
- The session on renewable energy technologies and building cooling, heating, and power systems discussed wind and hybrid systems, advances in photovoltaics, and recent breakthroughs in absorption and desiccant technologies that use waste heat from power generation to produce highly efficient space conditioning and healthier indoor environments.
- The session on interconnection and power quality was held at the Electric Power Research Institute's Power Electronics Application Center, which features a power quality testing facility and distributed generation park. Recognizing the importance of high-quality power supplies to businesses that rely increasingly on sensitive electronic components, this session discussed interconnection standards and power quality testing protocols.

The Showcase also included tours of several ORNL User Centers, a poster session, and a panel on partnership mechanisms.

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ORNL Signs up for Green Power

ORNL has become the first major industrial customer to sign on to the Tennessee Valley Authority's (TVA's) green power program, agreeing to purchase 675,000 kilowatt hours produced by renewable energy sources over the next year. ORNL and TVA's Public Power Institute have also agreed to collaborate on developing, demonstrating, and deploying efficient and renewable energy technologies.

The agreements support the Secretary of Energy's directive for DOE to use more renewable energy sources. ORNL's power procurement is the equivalent of the energy used by about 50 homes. Even this modest initial investment represents a significant environmental benefit: coal-fired plants burn 337 tons of coal to produce this much power in a year.

TVA hopes to be producing 8.7 megawatts of renewable energy by the end of 2000, including 225 kilowatt hours from solar energy, 2 megawatts from three wind turbines, and 6.5 megawatts from landfill gas facilities. With 28,502 megawatts of capacity, TVA is the nation's largest public power producer.

ORNL will pay a premium of 2.67 cents per kilowatt hour, or about $18,000 extra in a year, to help support TVA's $6.5 million investment in renewable energy sources. The $18,000 increase is a small fraction of ORNL's total energy bill. ORNL Director Bill Madia says the increase will be offset by the Laboratory's continued efforts to increase efficiency and reduce energy use. ORNL has reduced its power usage by nearly 20% since 1985.

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Is There a Diesel in Your Future?

Cleaning Up Diesel Emissions

Diesel engines are superior to other types of automobile engines in fuel economy and in carbon monoxide (CO) and hydrocarbon (HC) emissions. For that reason, diesels are the current engines of choice for the Partnership for a New Generation of Vehicles, which has a goal of producing vehicles that are up to three times as fuel-efficient as current vehicles of comparable size.

However, major challenges still face the acceptance of diesel engines, including reducing emissions of nitrogen oxides (NO_x) and particulate matter (PM) to levels that meet the Environmental Protection Agency standards scheduled to be phased in beginning in 2004. Research recently conducted at ORNL has led to the determination that diesels equipped with a new emission control system could meet the EPA standards.

Researchers at ORNL's Advanced Propulsion Technology Center achieved an emissions level of 0.05 grams per mile of NO_x from a light-duty diesel vehicle using a prototype NO_x adsorber and diesel fuel containing 3 ppm of sulfur (considered ultra-low-sulfur fuel). The system reduced the vehicle's NO_x emissions by more than 90% when the vehicle was run according to federal test procedures. A catalyzed diesel particulate filter was also installed and tested. It reduced PM emissions by more than 90% while performing comparably to a conventional system for CO, HC, and NO_x emissions. (The original equipment catalysts on the vehicle reduce PM by 30 to 40% but have little effect on NO_x.)

The Mercedes A170

When the catalyst system was treated to show results for the equivalent of 3000 miles on 30-ppm sulfur fuel, the added sulfur reduced the effectiveness of the system to about an 80% decrease in emissions. A similar performance loss could be expected after 30,000 miles using the fuel containing 3 ppm of sulfur. Therefore, some type of sulfur trapping technology will be necessary if currently available NO_x adsorbers are to be commercially viable. (Fuel sulfur has little effect on the performance of the original equipment catalysts.)

ORNL researcher Brian West installs hardware for emissions tests on the Mercedes A170 diesel vehicle.

The chassis dynamometer tests were conducted on a Mercedes A170 small diesel passenger car, using standard driving cycles and fuels with varying levels of added sulfur. Previous emissions controls evaluations have been mostly steady-state tests, aimed primarily at large, heavy-duty engines.

While the durability of the emissions reduction system has not been demonstrated, results indicate that there is hope for this efficient power plant to power our future.

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The POLYSYS analysis indicates that, if farmers received $40 per dry ton for switchgrass, an estimated 42 million acres could be planted at a profit greater than current agricultural uses. This acreage would increase net farm income by about $6 billion and would produce 188 million dry tons of biomass each year. That amount of biomass could supply about 7% of U.S. electricity needs or, if used to produce ethanol as a transportation fuel, it could displace more than 250 million barrels of oil. The 42 million acres would come from a mix of idle and pasture lands, land currently enrolled in the Conservation Reserve Program, and land planted in major crops. The model projects slight increases in traditional crop prices, ranging from 9 to 14%, resulting from the diversion of acreage to bioenergy crops. For the most part, these increases are within the range of market prices seen over the past 5 years.

More details, including the assumptions and scenarios used in the study, can be found in "The Economic Impacts of Bioenergy Crop Production on U.S. Agriculture," available at http://bioenergy.ornl.gov/papers/wagin/index.html.

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Testing the Mechanical Reliability of Electronic Ceramic Devices

Ceramic multilayer capacitors (MLCs), used in high-frequency circuits and switch mode power supplies, are exposed to dramatic temperature stresses that can cause them to fail. As demand grows for ever-thinner dielectric layers to accommodate miniaturization of electronics, it becomes more important to understand the stresses on MLCs and identify the flaws that can affect their functioning and reliability. Researchers at ORNL's High Temperature Materials Laboratory are working to understand and predict the mechanical performance of ceramic MLCs in order to improve their reliability and optimize their design.

Ceramic MLCs are complicated structures consisting of several different materials. Parameters that can affect their mechanical reliability fall into two categories: material parameters describe the dielectric ceramic's mechanical properties, and design parameters dictate the (thermo) mechanical stresses imposed on an MLC during its use or manufacture.

The ORNL researchers have used in-situ measurement to assess the mechanical strength of MLCs (Fig. 1 illustrates capacitor size). The strength distribution was calculated by using image analysis to measure the distribution of potentially strength-limiting flaws. The dielectric ceramic in three MLC sets contained two different and concurrent flaw types that were studied as potential strength-limiters: pores and secondary phase "inclusions" (Fig. 2).

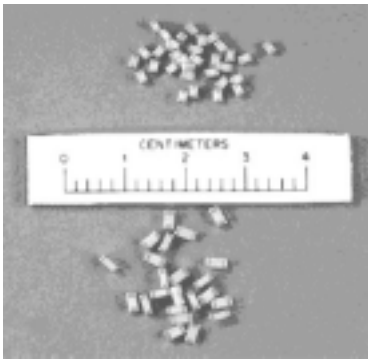

Fig. 1. Samples of MLCs of different sizes.

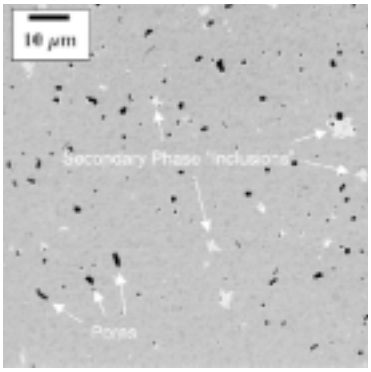

Fig. 2. Pores and inclusions in a sample of ceramic.

Recent studies focus on direct measurement of the three-point flexure strength of an MLC using a micro-mechanical test apparatus. Three stages, driven by computer-controlled stepper motors, enable precise positioning of a specimen. During the tests, a capacitor with nominal dimensions of 1.69 by 0.737 by 2.6 mm was placed on a three-point support fixture attached to a stage (Fig. 3), and a load was applied by raising the stage at a controlled rate to bring the specimen into contact with a fixed upper point. The strength data generated using this tool are being compared with indirect strength measurements from microscopic imaging.

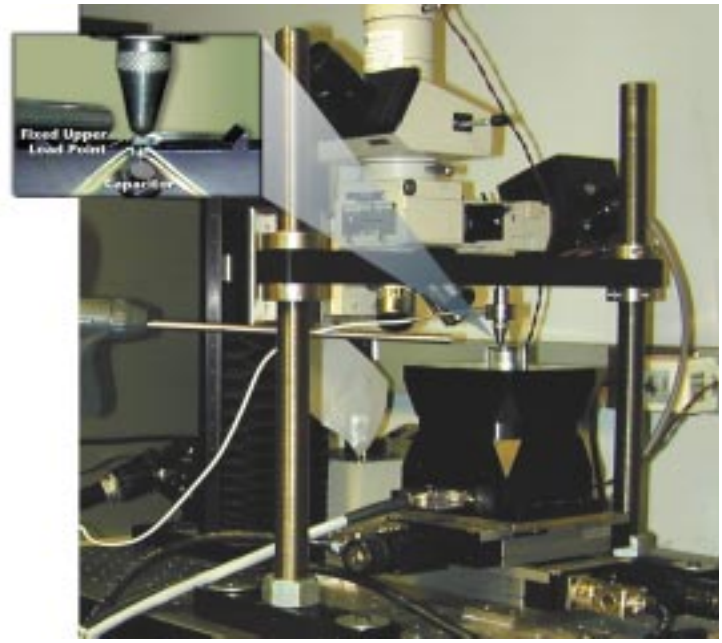

Fig. 3. This micro-mechanical test apparatus allows precise positioning of samples. The insert shows the three-point test fixture with a specimen.

It is hoped these mechanical analyses will help the makers and users of dielectric ceramic components understand why the components fail during use and ultimately help increase the service reliability of MLCs.

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National Transportation Research Center Becomes a Reality

Transportation is a key research area at ORNL and at the University of Tennessee, as well as a top employer in Tennessee and nearby states. The newly opened National Transportation Research Center—a joint venture of DOE, ORNL, UT, and the Development Corporation of Knox County—will combine the expertise of its partners to provide solutions to transportation challenges.

Researchers from ORNL and UT began moving into the $15 million, 83,000 ft^2 NTRC facility in October. The Center will have a combined annual R&D budget of more than $80 million and sponsors from private industry, state agencies, and the U.S. Departments of Energy, Transportation, and Defense. The NTRC offers capabilities in

- Vehicle and engine testing
- Commercial vehicle operations
- Infrastructure materials
- Power electronics/hybrids
- Materials packaging
- Materials modeling/simulation
- Intelligent transportation systems
- Human factors and safety
- Military transportation operations
- Transportation energy policy analysis
- Geographic information systems
- Advanced materials

The NTRC facility is expected to attract private-sector investment for transportation R&D.

ORNL's transportation-related research spans many scientific disciplines. Researchers are engaged in projects ranging from materials science—for a new generation of automobile bodies—to the development of cleaner, more efficient engines. NTRC will build upon ORNL's $45 million base with DOE EE/RE and $25 million base with other federal agencies and private industry. The center will bring much of this research activity together under one roof for the first time, facilitating collaboration among researchers in different disciplines.

UT brings another $20 million in funding from DOT and the State of Tennessee. UT also brings several nationally recognized R&D programs in transportation logistics and advanced vehicle technologies.

The Development Corporation brings the private sector to the relationship. Transportation-related companies with facilities in East Tennessee range from several multinational corporations to dozens of small, locally owned manufacturers. The pairing of transportation companies with research institutions is expected to attract significant private-sector investment from transportation-related firms.

The facility is located near the northeast corner of the intersection of Pellissippi Parkway and Hardin Valley Road.

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Sponsors: U.S. Departments of Energy, Transportation, and Defense, private industry, state agencies, and The Development Corporation of Knox County

New Digs for Power Electronics and Electric Machinery Research

New facilities and equipment will soon expand both the capabilities and the accessibility of ORNL's Power Electronics and Electric Machinery Research Center (PEEMRC).

This fall, the Center will relocate to 8,000 ft^2 of new laboratory space in the National Transportation Research Center. The new PEEMRC home will include some 5250 ft^2 of general laboratory space, plus dedicated areas for specific R&D functions. The new facility replaces about 6000 ft^2 of space located in a "racetrack" corridor, plus assorted laboratories converted from adjacent storage space, all in a 1940s-vintage building at the Oak Ridge Y-12 Plant.

A new 100-horsepower ac dynamometer and data acquisition system will greatly enhance the Center's capability to test components at simulated highway driving conditions (e.g., acceleration, deceleration) and test power electronics and electric machinery technologies in the regenerative mode (when power is being directed to the batteries or electric grid for storage). A second test cell in the facility has enough power capability to run a 400-horsepower dynamometer when funds become available to acquire it.

A new 100-hp dynamometer will improve testing of vehicle components and electronics.

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News Briefs

RABiTS Licensing Agreement Signed

Officials from ORNL and American Superconductor (ASC) signed a patent license agreement in May 2000 allowing ASC to develop and commercialize ORNL's RABiTS high-temperature superconducting wire technology. ASC is undertaking a major initiative to develop commercially viable "second-generation" HTS wires in partnership with ORNL, Los Alamos National Laboratory, Massachusetts Institute of Technology, and the Electric Power Research Institute. ASC will fund a collaborative R&D effort with ORNL to scale up the RABiTS technology from short samples of wire to 50- to 100-meter lengths in three years. RABiTS, or rolling-assisted, biaxially textured substrate, is a substrate that enables superconducting materials to carry unprecedented amounts of electric current compared with conventional copper or aluminum wires.

Klett Receives Brian T. Kelley Award

James Klett was presented the Brian T. Kelly award at the Annual International Carbon Conference for his research on carbon foam. The award is given by the British Carbon Group annually to a young scientist (under 35) who has made a significant contribution to the field of carbon science. The winner is selected by an international panel of judges who consider the quality of the nominees' work and the significance of their developments. It is one of only three annual awards given by the carbon science community. The award is a significant recognition of carbon materials R&D at ORNL.

Green Is Outstanding GEM

Johney B. Green, Jr., a member ORNL's Advanced Propulsion Team in the Engineering Technology Division, has been selected for the Outstanding GEM (Graduate Engineering Minority) Alumnus Award by the 2000 Black Engineer of the Year awards selection committee. The awards are given yearly to candidates in the ranks of the nation's highest achievers in technology. Johney leads ORNL's projects in spark ignition direct injection engines and is responsible for tests of the Plasmatron device. He is also a member of the Ford CRADA team on exhaust gas recirculation/cyclic dispersion.

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The new laboratory and test cells will provide important tools for validating the design of hybrid electric vehicle components and for the entire spectrum of power electronics and motors research already under way at ORNL.

The PEEMRC will participate in a workshop on power electronics for distributed generation systems October 26 and 27 in Knoxville. For more information, call John Kueck at 865-576-4454 (kueckjd@ornl.gov) or see www.epri-peac.com.

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