



# Impacting US Industry Today

A Snapshot of Innovative Solutions at Work for You



# Where Innovation Happens



Industry is the cornerstone of the American economy and the engine that drives innovation, job creation, and prosperity across the nation. It provides three indirect jobs for each direct one, but during the last decade, the number of manufacturing jobs has steadily declined due to increased global competition and rising energy costs.

To combat these increasing costs and advance energy independence and environmental sustainability, the US Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) is investing in clean energy technologies that reduce dependence on foreign oil while protecting the environment. It leverages partnerships with the private sector, state and local governments, DOE national laboratories, and universities to transform the nation's economic engine into one powered by clean energy.

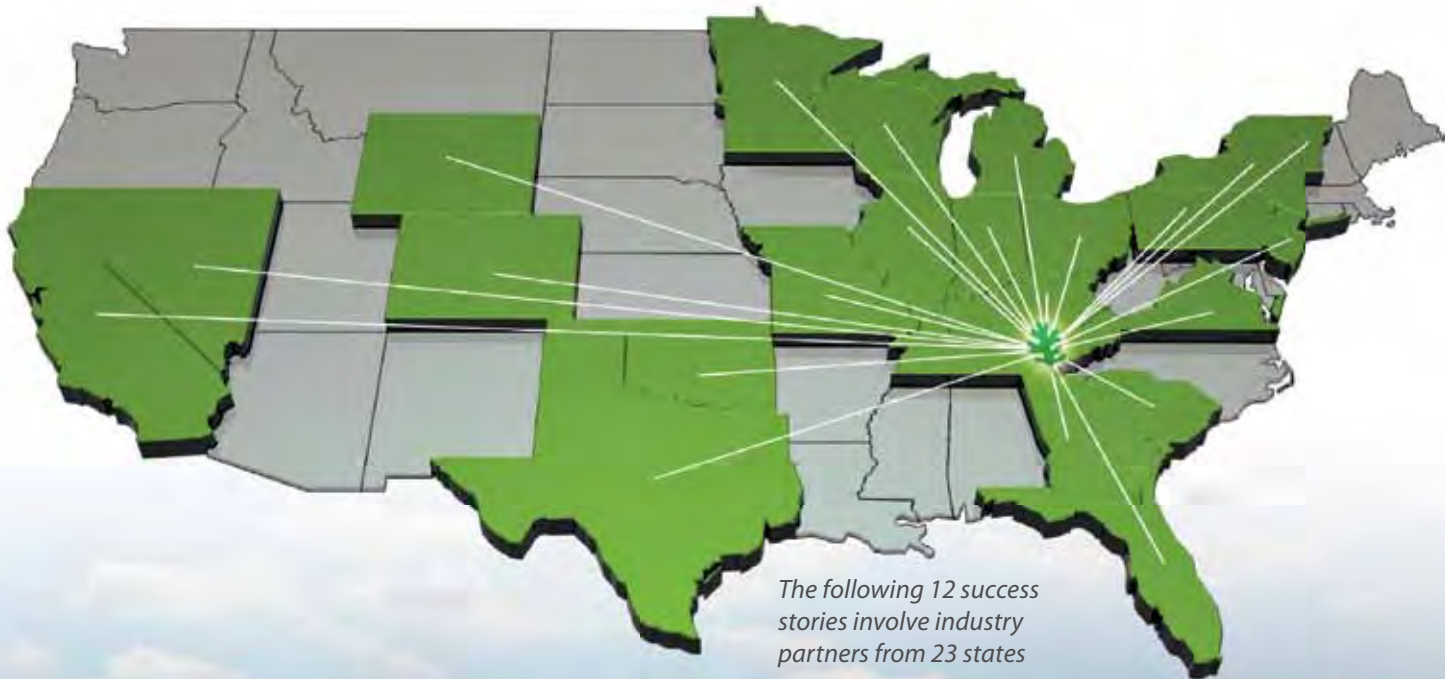
One such partner is DOE's largest energy lab, Oak Ridge National Laboratory (ORNL). With facilities and expertise beyond the reach of most private industries and educational institutions, ORNL addresses scientific needs of US industry through innovations in manufacturing, buildings, and transportation supported by investments from EERE's Advanced Manufacturing Office, Building Technologies Program, and Vehicle Technologies Program.







## EERE Programs at ORNL Showing Returns on Investment



*The following 12 success stories involve industry partners from 23 states*



# Advanced Manufacturing

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## Growing Companies

### Ford-Dow and ORNL Engage to Lower Carbon Fiber Costs

Carbon fiber is strong, stiff, and lightweight with high chemical resistance, high temperature tolerance, and low thermal expansion. It is commonly used in aerospace, civil-engineering, military, and competitive-sports applications.

#### ■ CHALLENGE

Its high cost relative to other reinforcing fibers limits carbon fiber's use in such high-volume industries as transportation, wind energy, infrastructure, and oil drilling.

#### ■ SOLUTION

ORNL operates DOE's only Carbon Fiber Technology Facility, which processes low-cost carbon fiber for industry development programs focused on lightweight structures and thermal management, among others, enabling more economical and technically viable materials for such uses.

#### ■ IMPACTS

- \$10+ million research agreement among Dow, ORNL/DOE, and state of Michigan launches Dow's carbon fiber work
- ORNL establishes Carbon Fiber Composites Consortium, a public-private partnership with 40+ companies, to accelerate commercial application
- Roane State Community College, in cooperation with ORNL, receives \$5.6 million to train technicians for the Carbon Fiber Technology Facility
- Consortium member Dow partners with Akso, world's largest producer of acrylic fiber, to develop and market carbon-fiber-based products
- Consortium members Ford and Dow team to bring low-cost, high-volume carbon fiber to next-generation vehicles



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## Charging Ahead

### Research Drives Threefold Cost Cut in US Automotive Batteries

Lithium-ion secondary batteries allow full electrification of automotive drivetrains and provide stationary energy storage solutions.

#### ■ CHALLENGE

Most lithium-ion batteries purchased in the United States are presently imported. US industry needs new technologies and materials to regain market dominance over nondomestic secondary battery manufacturers.

#### ■ SOLUTION

ORNL's researchers develop novel cathode materials with a projected doubling of automotive battery life, pointing to solutions that will extend it beyond 10 years.

#### ■ IMPACTS

- \$6.2 million research collaboration among ORNL; A123 Systems; Dow Kokam, LLC; Porous Power Technologies; and Planar Energy tackles critical manufacturing challenges
- Michigan Economic Development Corporation provides refundable tax credits for A123 Systems and Dow Kokam to construct battery manufacturing facilities and cost-shares ORNL battery research with Michigan companies
- Dow Kokam's 1200 MWh/year NANO production line is up and running
- New low-cost raw materials have >1000°C reduction in heat treatment and outperform commercial benchmarks; A123 Systems considers taking technology to commercial scale
- ORNL's proprietary water-based electrode processing reduces manufacturing cost up to 75%, raising industry interest





## Pioneering Innovations

### One Million Diesel Engines Switch to New Rugged Aluminum

Impellers designed for diesel engines are high-velocity rotors typically made from titanium to withstand harsh engine operating environments.

#### ■ CHALLENGE

Impellers are expensive, and industry needs a less costly alternative. While using aluminum would lower costs tenfold over titanium, traditional heating methods fail to produce an aluminum material that meets required mechanical properties for performance.

#### ■ SOLUTION

ORNL scientists patent a process for rapid infrared heating of aluminum forgings that results in improved fatigue life. Such heating is faster, cheaper, and less energy intensive than traditional gas-fired convection ovens.

#### ■ IMPACTS

- More than 1 million aluminum impellers manufactured for Cummins diesel engine turbochargers are on the road today
- 300,000+ aluminum impellers are sold annually
- 120-year-old Queen City Forging installs full-scale infrared furnace and becomes a pioneering supplier of aluminum components; manufacturing costs markedly drop due to 70% decrease in energy consumption, 5% decrease in downtime, and fourfold increase in production



## Emerging Markets

### Circuit Boards Print on Plastic in Less Than 1 Millisecond

Printed circuit boards are the backbone of America's high-tech environment. The average household uses more than 100 devices with circuit boards—from the refrigerator to the TV to the alarm clock.

#### ■ CHALLENGE

Most circuits are printed using outdated processes on rigid, flat surfaces. New devices such as photovoltaics, solid-state lighting, and flexible displays require flexible printed circuits using low-cost, high-throughput printing methods.

#### ■ SOLUTION

ORNL develops pulse thermal processing (PTP) technology, which can heat thin-film materials up to 600,000°C/second on low-temperature substrates such as plastics. PTP offers large-area processing with the ability to control diffusion on the nanometer scale, increasing throughput and providing more uniform microstructures along with consistent electrical and optical properties.

#### ■ IMPACTS

- NovaCentrix, a leader in printed electronics manufacturing technologies, licenses ORNL's PTP technology to develop next-generation PulseForge tools for thin-film and other applications
- Enabled by ORNL's PTP technology, NovaCentrix partners with Showa Denko K.K. in printed electronics for developing, manufacturing, and selling conductive inks
- DuPont Microcircuit Materials expands development of functional inks for the printed electronics industry using NovaCentrix PulseForge



# Building Technologies

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## Enabling Jobs

### Partners Improve Building Energy Use, Create Products and Jobs

Buildings consume 41% of the nation's energy, with 57% of that energy dedicated to controlling indoor environment, water temperature, and refrigeration.

#### ■ CHALLENGE

Industry and consumers want improved equipment efficiency to counteract rising costs, scarce resources, and climate change.

#### ■ SOLUTION

ORNL provides its decades of expertise in building energy use to industry partners, leading to more energy-efficient equipment, marketplace acceptance, and job creation.

#### ■ IMPACTS

- GE Appliances launches GeoSpring electric heat-pump water heater, which uses 62% less energy than standard equipment and pays for itself in less than 2.5 years; creates 100 GE manufacturing jobs in Louisville, KY, and approximately 1000 US jobs
- ClimateMaster launches Trilogy 40Q Mode, a variable-speed, geothermal (ground-source) integrated heat pump that reduces annual energy use as much as 65%
- Southwest Gas, under NextAire brand, launches an engine-driven, rooftop unit featuring heat recovery for space conditioning
- Frigidaire, GE, and Whirlpool develop technologies that produce 1kWH/day refrigerator-freezers, consuming 50% less energy than standard models



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## Guiding Investments

### ORNL Model Propels Vapor-Compression-Equipment Efficiency

Electric equipment uses 12.5% of the nation's energy in driving vapor-compression cycles—the heart of such equipment as air conditioners, heat pumps, chillers, and supermarket refrigeration systems.

#### ■ CHALLENGE

Unless industry drastically improves the efficiency of electric equipment, the goals of space conditioning and food preservation in developing countries will remain prohibitively expensive.

#### ■ SOLUTION

ORNL invents the Heat Pump Design Model (HPDM), a world-class, hardware-based vapor-compression model for research and product design that achieves improved efficiency levels.

#### ■ IMPACTS

- NORDYNE develops iQ Drive inverter-driven rotary compressor air conditioner, highest efficiency product on market in 2006, based on HPDM
- Emerson Climate Technologies, Inc., largest manufacturer with Copeland Scroll compressors, uses HPDM in system design
- National Appliance Energy Conservation Act bases some minimum efficiency standards on analysis using HPDM
- Montreal Protocol and US Clean Air Act adopt replacement refrigerants for chlorofluorocarbons and hydrochlorofluorocarbons using analysis based on HPDM





## Managing Moisture

### ORNL-Germany Partnership Tackles Moisture Management in Buildings

Faced with rising fuel and electricity costs, building owners and homeowners want improvements in energy efficiency.

#### ■ CHALLENGE

Improving building envelopes to gain energy efficiency in residential and commercial buildings can produce airtight and highly insulated buildings with moisture issues such as condensation, mold, rot, and freeze damage.

#### ■ SOLUTION

ORNL and Fraunhofer Institute of Building Physics (Germany) collaborate to develop WUFI (Wärme Und Feuchte Instationär), the world's most respected hygrothermal models for understanding the flow of heat, air, and moisture through envelope assemblies; storage of heat and moisture; and thresholds of failure.

#### ■ IMPACTS

- ORNL's test facilities measure essential property values needed by WUFI, providing product performance information for construction-materials industry
- WUFI data show up in codes, standards, and industry designs for new envelope assemblies and retrofits
- ORNL participates in developing first moisture-control envelope design standard (ASHRAE 160) adopted by General Services Administration (GSA P100)
- ORNL's hygrothermal research collaborations with industry (cool roofs, air barriers, insulation systems) result in affordable, moisture-durable products



## Maximizing Efficiency

### Prototype Buildings Provide Real-Life Testing, Reduce Risks

Evaluating preproduction prototypes of new energy-efficient products in realistic test beds is essential before starting full-scale manufacturing and introducing new products to market.

#### ■ CHALLENGE

Two options are available to industry for such testing: living labs (occupied buildings) and environmental chambers. However, use of living labs is intrusive and expensive, while chambers fail to reliably test all operating conditions encountered in a real building, resulting in unacceptable levels of manufacturing and market risks.

#### ■ SOLUTION

ORNL provides two additional options: (1) Through innovative public-private partnerships, ORNL leases new and existing houses for extended periods. Each house supports research and development on one envelope strategy and several generations of equipment, appliances, and controls. (2) ORNL establishes light commercial building test beds, providing realistic loads, operating conditions, and interactive effects.

#### ■ IMPACTS

- Research with the Tennessee Valley Authority and Schaad Companies on leased houses supports launches of GE GeoSpring heat-pump water heater and ClimateMaster Trilogy 40Q-Mode geothermal integrated heat pump
- More than a dozen industry partners participate in sharing costs of first-cycle research on ORNL's light commercial building flexible platforms
- ORNL develops automated building energy model tuning (to measured data) methodology for ongoing verification of operational efficiency



# Vehicle Technologies

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## *Solving Problems*

### CF8C-Plus Stainless Steel Takes on Extreme Heat in 35,000 Diesel Engines

Advanced diesel engines provide improved fuel efficiency and lower emissions but require their components to endure extreme temperatures exceeding 750°C.

#### ■ CHALLENGE

Commercial cast steels such as CF8C are desirable for these applications but cannot withstand temperatures above 600–650°C.

#### ■ SOLUTION

ORNL develops CF8C-Plus, an ASTM-International-standard-approved low-cost cast stainless steel that tolerates extreme temperatures (650–900°C) in diesel engines, gas turbines, and nuclear reactors; is resistant to mechanical and thermal fatigue and age-induced failure; and is more castable than standard steel.

#### ■ IMPACTS

- Caterpillar's Regeneration System uses 550 tons of CF8C-Plus in more than 35,000 heavy-duty highway diesel engines for a net savings of nearly \$23 million in manufacturing costs
- Honeywell Turbo Technologies is testing CF8C-Plus in both diesel- and automotive-engine turbocharger applications
- Solar Turbines, Inc., deploys CF8C-Plus in a 4.5 MW Mercury 50 gas turbine engine at the 29 Palms US Marine Corps Base in California
- Trial licenses are in place with companies such as GE and Stainless Foundry & Engineering, which obtained the first commercial license in May 2008



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## *Measuring Stress*

### Test Center Predicts, Minimizes Residual Stress in Vehicle Parts

Materials used in components for automotive and diesel engines are subjected to rapid changes in temperature and other forces that may cause deformities and stress formation during both the manufacturing process and while on the road.

#### ■ CHALLENGE

Residual stress eventually leads to degraded mechanical performance, stress-corrosion cracking, shortened lifetime, and even catastrophic failure.

#### ■ SOLUTION

ORNL's Residual Stress User Center conducts nondestructive testing of engine components using neutron and X-ray technologies to help industry determine (1) which manufacturing processes minimize the generation of residual stresses; (2) whether an object can tolerate specific demanding applications; and (3) whether heat treatment (annealing) can contain, eliminate, or reduce residual stresses.

#### ■ IMPACTS

- Honeywell Turbo Technologies measures residual stress on shaft-wheel-assembly weld joints of vehicle turbochargers used in automobiles and trucks to improve design and manufacturing process
- Upcoming collaborations with Honeywell include evaluating cost-effective ways to mitigate residual stresses, extend component life, and ensure reliability of shaft wheel assembly and turbine housing in its turbochargers





## Analyzing Within

### Chrysler-Cummins Meets Emission-Control Standards 3 Years Early

The transportation sector accounts for 70% of the US oil demand and offers vast opportunities for reducing environmental effects of vehicle exhaust.

#### ■ CHALLENGE

Advanced engines such as clean diesels contribute to meeting emission standards but require highly effective exhaust treatment technologies to meet stringent emissions regulations.

#### ■ SOLUTION

ORNL and Cummins collaborate to develop diagnostic tool SpaciMS to gain insights into catalyst devices, after-treatment systems, and engine performance. SpaciMS measures and maps concentrations of gaseous pollutants such as nitrogen oxide, carbon monoxide, and carbon dioxide and is widely used in catalyst research including for fuel cells and fuel reformers.

#### ■ IMPACTS

- Cummins uses SpaciMS in its engine development and calibration, resulting in Chrysler's 2007 launch of the Cummins-powered Dodge Ram pickup truck—fully compliant with 2010 environmental standards
- SpaciMS allows Cummins to quantify speciation of exhaust gases in a new way and becomes a mainstay of its after-treatment system development
- Hiden Analytical commercializes SpaciMS technology for determination of intracatalyst reactor chemistry and introduces the first commercially available instrument of its kind



## Restarting Production

### Advanced Materials Answer Demands for Reliable, Sophisticated Parts

The automotive industry needs new materials such as ultra-high-strength steels to manufacture lighter, safer vehicles at price points consumers will embrace.

#### ■ CHALLENGE

Hot-stamped parts for chassis components now account for more than 107 million parts per year. Problems that occur during manufacturing are costly and difficult to resolve, involving lost production time and revenues.

#### ■ SOLUTION

ORNL's High Temperature Materials Laboratory (HTML) is a highly sophisticated, experimental user facility that offers unique, specialized technologies, instrumentation, and expertise. It specializes in characterizing advanced materials, such as structural ceramics; metal-, ceramic-, and polymer-matrix composites; lightweight and light-weighting materials (aluminum and magnesium alloys and high-strength steels); and nonstructural functional materials.

#### ■ IMPACTS

- ORNL assembles a team to assist Cosma International, a global automotive parts supplier, in solving a problem that interrupted components production and vehicle assembly at an original equipment manufacturer (OEM) plant
- ORNL's team produces rapid-response solutions, and OEM and 800 employees in Cosma's 334,000 ft<sup>2</sup> facility resume production





## Addressing the Challenges of Tomorrow, Making a Difference Today

Development and commercial deployment of next-generation technologies remain essential to America's long-term economic competitiveness and energy independence. As linchpins of real-world applications, new technologies both revitalize existing industries and support emerging ones. Today's advances produce a host of innovative products for jet aircraft, computers, building technologies, and vehicles along with advanced instruments, next-generation materials, and improved processing methods.

ORNL has ongoing collaborative relationships with more than 800 companies and distinction as DOE's leading recipient of R&D 100 Awards among the national laboratories. The lab demonstrates the ability to work with US manufacturers and transition technologies that will drive innovation in the coming decades. From concept to commercialization, ORNL's world-leading facilities and researchers work to reduce energy demands, develop new products, and strengthen our nation's clean-energy economy to meet the commercial and national security needs of tomorrow.











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