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NEWSLETTER OF *Oak Ridge National Laboratory's Energy and Environmental Sciences Directorate*

Breakthroughs in Biosciences

Collaborating with Computing on large-scale simulations, massive data collection

Mike Leuze

Dave Ussery

Arjun Shankar

Jeremy Smith

Dan Jacobson

Over the past several decades, biology research such as genome sequencing has resulted in enormous amounts of data to be managed, stored, and analyzed. But that is not work for your average desktop computer, so Biosciences Division (BSD) researchers at the US Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL) are increasing collaborations with experts from the lab's Computing and Computational Sciences Directorate (CCSD).

Some computing experts have taken up residence in offices inside BSD facilities. Mike Leuze, group leader for the CCSD Computational Biomolecular Modeling and Bioinformatics Group, has an office next door to BSD's Dave Ussery, a molecular biologist and group leader for the Comparative Genomics Group, in a Biosciences building on the west side of the ORNL campus.

Leuze said his team and Ussery's team collaborate on large-scale projects that involve molecular dynamics and bioinformatics. "We are computational scientists, but our focus, our specialization, is biology, and so I chose to sit next door to Dave because I feel like to really foster the collaboration between the computational side of the lab and the biology side of the lab, a weekly meeting is not enough," Leuze said.

One of the key changes leading to the increased collaboration is the cost of computing. Models, simulations, and analyses on computers are faster and cheaper than ever before. More affordable research means new opportunities and greater accessibility to a larger number of researchers. Ussery said the sequencing of the first bacterial genome cost about $1 million. Now, Ussery said, you can sequence a genome for less than the cost of a cup of Starbucks coffee—maybe in less time than the barista can fix that cup. And computing is on the brink of a major milestone in speed: exascale. Although it is still a few years away, the astounding speed of exascale computing, which is 10^{18} operations per second, is clearly within sight.

"It's a very, very large number," Ussery said. "Basically, you could process essentially all of the DNA sequences that we've done so far in 1 second. And then what? So the question is, 'What do we do with this computational power?'"

The answer is coming with help from Leuze and other computing experts, such as Mallikarjun (Arjun) Shankar of the CCSD Computational Data Analytics Group.

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OAK RIDGE National Laboratory

in focus letter

Tony Palumbo (left) and Paul Gilna (right)

Biosciences Division thrives on collaboration in pursuit of scientific breakthroughs

A collaborative environment often is a key to success. For ORNL's Biosciences Division (BSD), it's considered *critical* to success. Our diverse projects require collaboration not only from our experts but also across scientific disciplines, with other ORNL directorates and even external partners.

Take, for example, Jerry Tuskan's work on the *Populus* genome (see page 6). Jerry leads a team that first sequenced a single *Populus* tree (cottonwood) genome, a significant triumph about a dozen years ago that was highly visible in the scientific community. The team, including the Joint Genome Institute (a DOE Office of Science User Facility managed by Lawrence Berkeley National Laboratory), has since sequenced another 1,000 *Populus* genomes, thus enabling the BioEnergy Science Center's (BESC's) studies of genome differences and characteristics for potential applications in bioenergy.

The amount of data the team has generated is stunning—and simply couldn't be managed or analyzed without the expertise of ORNL's high-performance computing (HPC) capabilities. We want to continue to bring computing's tools to bear on our science. Genome sequencing costs will decrease, which means we'll be able to expand work like Jerry's. Switchgrass has an even larger, more complicated genome than *Populus*. We are just scratching the surface right now; as we move deeper into this research, we will generate even more overwhelming data sets.

BESC is a prime example of the collaborative environment at ORNL. Led by ORNL, BESC is part of a DOE program to conduct research that could lead to an increase in efficiency of biofuel production from lignocellulosic biomass (separate from conventional corn-based biofuels), thereby reducing our nation's dependence on petroleum-based fuels. BESC's focus (particularly with *Populus* and switchgrass) is on reducing plant recalcitrance, or a plant's ability to resist decomposition and, therefore, resist breaking down into sugars.

BESC has successfully identified many modifiable plant traits to decrease recalcitrance. With a decrease in recalcitrance, increased sugar production per plant means reductions in the amount of land needed to grow the crops and in ethanol production costs. One of the many roadblocks to economically viable ethanol production is land use—we need to find ways to obtain sugars from plant sources that are not competing with food production. Grasses such as switchgrass establish easily in soil and don't require much in the way of soil nutrients or water, so they can be cultivated successfully on land that is not rich enough to support food-based crops. If we can reduce switchgrass's recalcitrance and if farmers then plant it on poorer-quality fields, we've overcome that roadblock.

Seven years into DOE's model of large-scale science at hubs or centers, BESC is achieving successes because of the strength of its partnerships: it's a consortium of 18 organizations with expertise in biological, chemical, physical, and computational sciences; mathematics; and engineering. BESC has developed a culture that places a high value on collaborative science. We get more for DOE's investment through that value because we are focused not only on what we need to accomplish but also on how best to accomplish it.

Probably the most critical part of our collaboration success is our people. ORNL's expertise in big data systems is critical; BESC's partnerships are strong; and the lab's equipment and facilities in other directorates are world class. But it all really comes down to the people—BSD's scientists—who know how to leverage all these benefits while working together on emerging science. Throughout this issue of *Clean Energy* are several articles about their groundbreaking research in biosciences and bioenergy.—*Tony Palumbo and Paul Gilna*

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in the spotlight

Art Ragauskas

Governor's chair splits time between ORNL, University of Tennessee in search of biorefining solutions

For most of the past year, the Biosciences Division's Art Ragauskas has divided his time pursuing solutions in biorefining between labs and offices at ORNL and the University of Tennessee (UT) in Knoxville.

In 2014 Ragauskas was appointed the UT–ORNL Governor's Chair for Biorefining, based in UT's Department of Chemical and Biomolecular Engineering with a complementary appointment in the UT Institute of Agriculture's Department of Forestry, Wildlife, and Fisheries. At ORNL, he continues his longstanding involvement with the BioEnergy Science Center (BESC). As a founding member of BESC, Ragauskas served for a number of years as the lead scientist of the Georgia Tech team researching the in-depth cell wall characterization of pretreated switchgrass and poplar biomass.

At ORNL, his work focuses on full utilization of biomass and conversion to biofuel, bio-based chemicals, materials, or power; he is studying biological conversion pathways, or methods to convert poplar and switchgrass biomass into biofuels. At UT, his efforts involve thermal–chemical treatments to convert biomass to biofuels, with emphasis on green diesel and green gasoline, as well as lignin conversion research.

BESC researchers are pursuing fundamental answers to a particularly costly, complicated aspect of biomass production—overcoming recalcitrance to convert biomass to ethanol or other biofuels with little or no remaining residue. They are targeting genetic manipulations and examining structural changes of cellulose, hemicellulose, and lignin components to improve the next generation of biomass.

Ragauskas also is intrigued by biomass's potential for use in bio-based materials, such as carbon fiber and—although it's conceptual right now—even additive manufacturing. Potential applications include plastics, products currently derived from petroleum (i.e., polyurethane foam), additives for antioxidant agents, and reinforcing materials for advanced composites. "We're pushing the boundaries of science into the area of practical applications and having an impact on real life," he said.

A year into his Governor's Chair role, Ragauskas praises ORNL staff for their willingness to collaborate, noting that neutron scientists, computational modelers, geneticists, sustainability experts, and lignin carbon fiber researchers all have vital roles in his research. "I've always gravitated to interdisciplinary research," he said. "The people here drive efforts to initiate collaborations. Those things link together beautifully on this campus."

In 2014, Ragauskas and 15 other scientists published a high profile paper in *Science* titled "Lignin valorization: Improving lignin processing in the biorefinery." Citing it as another example of successful collaboration, he notes that half of the authors are ORNL staff: besides Ragauskas, they are BESC's Brian Davison, Paul Gilna, Timothy Tschaplinski, and Jerry Tuskan; Martin Keller, associate laboratory director for energy and environmental sciences; Paul Langan of the Neutron Sciences Directorate; and Amit Naskar of the Physical Sciences Directorate. "I couldn't have written this myself," Ragauskas said. "I needed the collaboration."

Although his schedule pulls him between two locations, one commonality with the two roles that Ragauskas particularly values is the opportunity to work with and mentor undergraduate and graduate students in labs at both locations. Although not currently teaching, he plans to return to the classroom at UT eventually. "Any of us that are in this field of bioenergy have, in my opinion, a moral responsibility to make sure the next generation has as much passion as we do," Ragauskas said.—*Wendy Hames*

(continued from cover)

Shankar said biologists are using computing to good effect in their research, and one of the results is the creation of a growing number of large-scale databases such as those for genome sequencing. "The scale and ability to manage these databases has dramatically increased," he said. "This is where our directorates are coming together."

Shankar directs the Compute and Data Environment for Science, or CADES, a CCSD initiative to help researchers from other ORNL directorates create, harness, collect, store, and analyze data. "It's a realization of the convergence of computing and data," Shankar said. "Biology is hugely data driven."

BSD's Jeremy Smith, director of ORNL's Center for Molecular Biophysics and a University of Tennessee–ORNL Governor's Chair, has multifaceted expertise that bridges the gap between computing and biology. He and his group use computational science to solve problems in the energy biosciences, such as overcoming recalcitrance of biomass for deconstruction into useful molecules such as sugars.

Smith's group includes 25 computational scientists who write or help develop programs for biological studies. The advantage of being on site at ORNL is that CCSD has a large number of talented computational and computer scientists with whom Smith's group can interact and develop programs.

"With computers, we can do large-scale computer simulations of the dynamics of biomass—in other words, the motions and the structures of plant cell walls," said Smith, noting that his group has done some of the largest simulations ever completed in biosciences research.

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Delivering innovation: ORNL to unveil AMIE demo project

The additive manufacturing integrated energy project engages numerous industry partners including Skidmore, Owings & Merrill; 3M; Alcoa; Clayton Homes; Cincinnati Incorporated; GE Appliances; NanoPore; Tru-Design; and the University of Tennessee.

ORNL has internally funded a new research project to tackle some of the world's challenges in accessing reliable, resilient, and affordable electricity. Working with industry partners, the additive manufacturing integrated energy (AMIE) team is leveraging the combined capabilities of four ORNL research areas—additive manufacturing, building technologies, vehicle technologies, and integrated energy systems—to develop a 3-D printed building and vehicle with innovative integration of energy systems.

"We're looking at large community issues from the single-unit level," said Martin Keller, associate laboratory director for energy and environmental sciences. "Our research provides solutions on a small scale, which will translate to a significant reduction in energy use and an increase in cost savings when ramped up to a national, and even global, level."

ORNL will demonstrate the AMIE project for the first time at the DOE Office of Energy Efficiency and Renewable Energy Industry Day event at ORNL on Sept. 23–24.—*Sara Shoemaker*

ORNL to host first DOE-sponsored Industry Day event

Tech to Market
EERE Industry Day 2015

ORNL will host the inaugural DOE Office of Energy Efficiency and Renewable Energy (EERE) Industry Day event Sept. 23–24 to introduce new energy efficient innovations in buildings, transportation, and advanced manufacturing and to facilitate public–private partnerships and collaborations that will enable these technologies to enter the market.

EERE Industry Day is sponsored by the Building Technologies, Advanced Manufacturing, and Vehicle Technologies Offices within EERE.

The goal of Industry Day is to introduce small businesses to EERE capabilities and to promote ways that small businesses can increase their interactions with ORNL and other DOE laboratories. Activities will include networking sessions with industry stakeholders, technical experts, and financial advisors to explore opportunities for advancing innovations; discussions of the challenges preventing game-changing new technologies from mass adoption; demonstrations of a 3-D printed building envelope and vehicle; tours of some of ORNL's world-class facilities; information about a new model for rapid innovation that involves crowdsourcing and prototyping designs using 3-D printing; and recognition of the best ideas generated during a recent ORNL crowdsourcing website effort.

Last spring, the Building Technologies Research and Integration Center launched the ORNL Buildings Crowdsourcing Community—the lab's first external crowdsourcing website—as a forum for technology innovators to gather feedback from customers and other stakeholders about next-generation building technologies. Approximately 360 users posted 71 new technology design ideas in three categories: equipment and appliances, sensors and controls, and envelope technologies. Participants voted on the various ideas and provided comments that promoted discussion and valuable feedback. After the Building Technologies Office–sponsored crowdsourcing website closed, an independent panel of experts reviewed the most popular submissions, and the best ideas will be recognized at Industry Day.—*Sara Shoemaker*

(continued from page 1)

Most BSD researchers do not have Smith's level of computing expertise, so CCSD professionals like Shankar and his team offer their expertise to researchers who need computing power but who do not possess the knowledge or skills to use high-performance computing. The work is often challenging. "We have to design systems better, create better analysis capabilities, and build new software and middleware to connect systems," he said. "That's forcing us to stay on our toes."

One focus for computational experts like Shankar is making new computer capabilities not just useful but also easy for biosciences researchers to use. "When that's done well, everyone's happy," he said.

Computational biologist Dan Jacobson came to ORNL in late 2014 to expand BSD's collaborations with computing. "That was the attraction of ORNL for me, this combination of some of the world's largest biological data sets with, obviously, one of the world's largest supercomputing infrastructures," he said. "But it's taking a lot of work to put that all together in a way that actually works for computational biology."

Jacobson is working with CADES and the Oak Ridge Leadership Computing Facility (OLCF) to develop what computational biologists need, such as computer architectures with a big memory footprint. CADES and OLCF, a DOE Office of Science User Facility at ORNL, have varied approaches that fulfill different, but crucial, needs.

"We're at an interesting place in biology, where the scale of biology has changed pretty radically since the beginning of the genome project, and it's truly exponential, the amount of data that's coming out every day, every month, every year," Jacobson said. "That gives us unprecedented opportunities, but also unprecedented challenges."—*Wendy Hames*

ESD researchers document hydropower resources, trends in milestone DOE report

The overall status of the US hydropower fleet—including factors such as capacity, location, ownership, economic impacts, market trends, and performance indicators—has been compiled for the first time into a single document, DOE's *2014 Hydropower Market Report*.

A team of ORNL Environmental Sciences Division researchers prepared the comprehensive hydropower report, released in April, for the Wind and Water Power Technologies Office of the DOE Office of Energy Efficiency and Renewable Energy. ORNL researchers Rocío Uría-Martínez, Patrick O'Connor, and Megan Johnson, with support from ORNL's Nicole Samu and Connor Waldoch, spent about a year developing the 100-page report.

The Wind and Water Power Technologies Office had 8 years' worth of comprehensive reports on wind power, but nothing comparable was available on hydropower, which provides about 7% of the nation's electricity—enough to power more than 20 million homes.

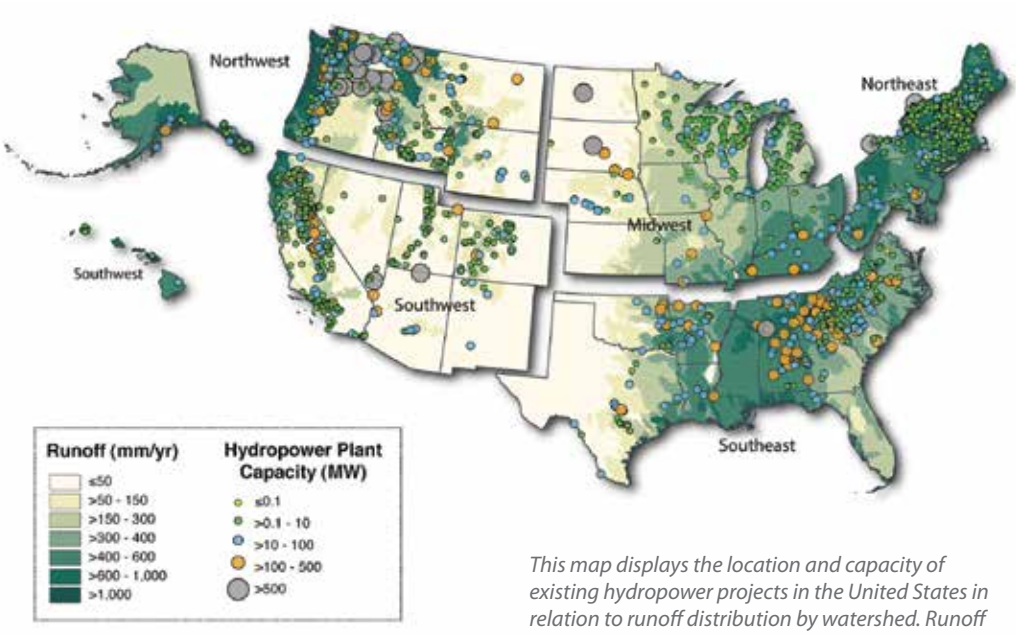
"ORNL was in a unique position to develop this report because the lab has been studying hydropower for decades," Uría-Martínez said.

One of the main sources the team mined for data was the ORNL-managed National Hydropower Asset Assessment Program database, which was DOE's first attempt to gather comprehensive hydropower statistics into a single location, Johnson said.

The report is intended to be the first source for a broad audience of policymakers, congressional staffers, industry professionals, and other interested individuals for objective information about the size, scope, and variability of this critical, clean power generation technology.

Hydropower is vital to supporting the US electric grid because it is available at all times, and many plants can produce power on demand. As the largest renewable power source in the United States, hydropower has a long history; in fact, the fleet of nearly 2,200 existing plants includes some 100-year-old facilities.

The current US hydropower fleet has a total capacity of 79.64 gigawatts and has experienced a net capacity increase of nearly 1.5 gigawatts from 2005 to 2013. Capacity additions to existing projects accounted for 86% of the increases.



This map displays the location and capacity of existing hydropower projects in the United States in relation to runoff distribution by watershed. Runoff was calculated based on the best available data.

Source: ORNL NHAAP Existing Hydropower Assets Data Set. U.S. Geological Survey-Watershed Boundary Data Set. 2000 Census-State Boundaries.

"For hydropower plants built before 1970, long-term generation data show that the number of megawatt-hours produced per megawatt of capacity installed has decreased over time," Uría-Martínez said. "Not quite as much power is being generated now."

Reasons for this decreasing trend in generation among older hydropower plants include changing environmental regulations, climate change effects on water availability, aging turbine-generator units, and reallocation of the water stored in reservoirs from hydropower to other uses.

Alongside the almost 80 gigawatts of installed hydropower capacity, there are an additional 21.6 gigawatts of pumped storage hydropower, which account for 97% of utility-scale electrical energy storage in the United States. These plants cycle water between an upper and a lower reservoir. Water is pumped—consuming electricity in the process—from the lower to the upper reservoir when electricity is cheap, and water is released from the upper reservoir to generate electricity when electricity is most valuable.—*Wendy Hames*

Danielson touts ORNL strengths in April lab visit

David Danielson, DOE Assistant Secretary for Energy Efficiency and Renewable Energy (EERE), visited ORNL April 8 with an itinerary that included a Memorandum of Understanding (MOU) signing.

GE Appliances will work with ORNL through the MOU, signed by Laboratory Director Thom Mason and GE Appliances R&D Director Natarajan (Venkat) Venkatakrishnan, to evaluate the potential for innovative products before making significant multimillion-dollar investments through its FirstBuild Program. GE Appliances will tap ORNL's Building Technologies Research and Integration Center (BTRIC) and Manufacturing Demonstration Facility to help move new products and manufacturing techniques into full production.

At BTRIC, staff briefed Danielson on the research and development of technologies for home and supermarket refrigeration, clothes dryer equipment, and residential and commercial building insulation applications that will result in energy and cost savings and lower global warming emissions.

Also during his visit, Danielson explained elements of the EERE National Laboratory Impact Initiative at a meeting with lab staff. The initiative supports the relationship between EERE and the national laboratory enterprise.—*Bill Cabage*

General Electric Appliances R&D Director Natarajan (Venkat) Venkatakrishnan (front left) and ORNL Laboratory Director Tom Mason (front right) signed a Memorandum of Understanding in April during a laboratory visit by DOE officials. Standing, from left, are Joyce Yang, director of DOE Energy Efficiency and Renewable Energy's (EERE's) National Laboratory Impact Initiative; Roland Risser, director of the DOE Building Technologies Office; David Danielson, assistant secretary for EERE; and Mark Johnson, director of the DOE Advanced Manufacturing Office.

ORNL's Ayyoub Momen (left) demonstrates ultrasonic clothes dryer technology for David Danielson (right), assistant secretary for Energy Efficiency and Renewable Energy (EERE); Joyce Yang (second from right), director of EERE's National Laboratory Impact Initiative; Roland Risser (center), director of the DOE Building Technologies Office; and Mark Johnson (second from left), director of the DOE Advanced Manufacturing Office. The group toured ORNL's Building Technologies Research and Integration Center on April 8.

ORNL collaborates with GE Appliances to develop world's first heatless dryer

ORNL researchers are collaborating with General Electric (GE) Appliances to develop the world's first ultrasonic clothes dryer; this technology could forever change the concept of residential heat-drying technology.

Electric clothes dryers are among the largest energy consuming appliances used during peak time in US households. ORNL's novel approach extracts water mechanically from fabric using high-frequency vibrations generated by piezoelectric transducers. This process raises moisture from clothing into a fine mist that can be removed by room temperature airflow.

The technology could make a full-sized clothes dryer three to five times more energy efficient than conventional heat dryers and reduce drying time to 15–20 minutes, with virtually no shrinkage, fading, or lint production.

"When I put a very small piece of fabric on top of these transducers, the fabric went from completely wet to completely dry in just 14 seconds," said Principal Investigator Ayyoub Momen. "It was quite amazing to see."

ORNL is currently is in the process of patenting this invention. The research team hopes to have a working prototype unit by August 2016. Funding for this project was competitively awarded by DOE's Building Technologies Office in 2014.—*Sara Shoemaker*

Additive manufacturing process boosts new refrigeration technology development

A building technologies project with General Electric (GE) Appliances to revolutionize 100-year-old home refrigeration technology has tapped into ORNL's advanced manufacturing and materials science expertise to explore ways to improve manufacturing processes and overall energy efficiency.

A drastic upgrade in refrigerator design using magnetocaloric materials (MCM) eliminates the need for refrigerants but creates a new challenge—how to transfer heat to or from the solid MCM using a heat transfer fluid. Energy and Transportation Science Division researchers Ayyoub Momen, Omar Abdelaziz, and Ed Vineyard are innovating new circuit seal and hydraulic solutions to create a feasible design.

ORNL's early results in employing MCM for both residential and commercial refrigeration show the technology is a promising alternative to the vapor compression systems used in today's appliances; it could theoretically reduce energy consumption by 25% and eliminate the need for refrigerants and their associated global warming potential should they leak into the atmosphere.

ORNL and GE have been working on this project through a Cooperative Research and Development Agreement since March 2014, and GE hopes to commercialize magnetocaloric refrigerators for use in homes by 2020. GE is self-funded, and the DOE Building Technologies Office sponsors ORNL's effort through the Annual Operating Plan process.—*Sara Shoemaker*

IACMI formally launches at inaugural meeting in Knoxville

A signing ceremony in June between representatives from DOE and the Institute for Advanced Composites Manufacturing Innovation (IACMI) marked the official start of business for the newly established institute, which was announced in January by President Barack Obama. ORNL and the University of Tennessee are among IACMI's founding research partners.

IACMI will work with industry to reduce technical risk and develop a robust supply chain for advanced composite materials in automotive components, wind turbines, and compressed gas storage applications. Funded with $70 million in federal funds and more than $180 million in nonfederal funds, IACMI will focus on making advanced fiber-reinforced polymer composites less expensive and less energy-intensive, helping give America's resurging manufacturing sector a more competitive edge in the global economy.

The IACMI team—a 123-member consortium headquartered in Tennessee—is led and operated by a not-for-profit established by the University of Tennessee Research Foundation that connects the world's leading manufacturers across the supply chain with universities and national laboratories pioneering advanced composites technology development and research.

IACMI is the fifth institute chosen in support of the president's overall vision for the National Network for Manufacturing Innovation. The public-private partnership was selected through a competitive process led by the Advanced Manufacturing Office within DOE's Office of Energy Efficiency and Renewable Energy. —*Morgan McCorkle*

Uday Vaidya

Advanced composites expert named newest UT–ORNL Governor's Chair

Uday Vaidya has been named the University of Tennessee–ORNL Governor's Chair in Advanced Composites Manufacturing.

"This is a significant opportunity to provide leadership and serve as a bridge between UT, ORNL, industry, and academic partners," said Vaidya, who also will serve as a professor in UT's Department of Mechanical, Aerospace, and Biomedical Engineering. "The industry is in urgent need of trained engineers with comprehensive knowledge in the design, modeling, and manufacturing of advanced materials—including composites—and many of those innovations are possible through a comprehensive ecosystem such as the one our institutions provide."

Vaidya, who comes from the University of Alabama at Birmingham, added that those innovations will help keep UT and ORNL at the forefront of research. The work is also important to the economy of the United States and to its position as a global leader in the automotive, energy, and aerospace industries, which are trending toward the use of lightweight yet durable carbon fiber construction.

Currently, producing such materials in large quantities can be cost prohibitive, but UT, ORNL, and the new Institute for Advanced Composites Manufacturing Innovation can make them more readily attainable, according to Vaidya.

Boosting biofuel

Researcher seeks ways to free sugars from recalcitrant lignin

As one of DOE's model bioenergy species with incredible potential for biofuel production, the *Populus* tree (cottonwood) is challenging researchers with its recalcitrance. A recalcitrant plant does not easily yield its sugars for conversion to transportation fuel; *Populus*, for example, has a thick cell wall that stubbornly protects the sugars contained inside.

According to Jerry Tuskan, an ORNL Corporate Fellow and a distinguished scientist in the Biosciences Division's Plant Systems Biology Group, *Populus* plants contain two types of sugar polymers—cellulose and hemicellulose—as well as lignin, a mesh-like matrix within the cell wall to strengthen the plant and enable upright growth. That strength also leads to recalcitrance.

To release these vital sugars, scientists can reduce the amount of lignin or increase the amount of sugar. Both methods work, so Tuskan and his team have taken a discovery-based approach to determine which is more efficient.

Staff scientists such as Wellington Muchero, looking at a lignin-related gene called EPSP synthase, discovered that EPSP controls the flow of carbon in and out of the lignin pathway. This study resulted in a method for a 23% reduction in lignin and a 200-fold increase in sugar release.

In a separate effort, staff scientist Jay Chen and post-doc Tony Bryan are studying the gene *Angustifolia*, which was previously recognized only in mammalian systems. Researchers now know that *Angustifolia* is contained in *Populus* and is associated with improved sugar release.

Results from the 2006 completion of the *Populus* genome, led by Tuskan and an international team, have enabled scientists to begin to understand the mechanisms of plant adaptability that have led to today's research. Through DOE funding and in collaboration with the Joint Genome Institute, Tuskan's team subsequently sequenced the genomes of 1,000 unrelated *Populus* plants to learn how the genomes of each plant differed from the others. Through gene sequencing, according to Tuskan, "we looked at every single gene in each of those 1,000 genotypes."

The result is probably the world's largest publicly available plant genomics database at 1.2 terabits (or *1.2 trillion* binary digits). "Any manipulation or analysis of that data requires high-performance computing infrastructure," Tuskan said. The volume of calculations, adjustments for relationships among genes, and correction for false discovery rates would require literally months on a standard computer. Working with BSD staff scientist Dan Jacobson and Bredesen Center graduate student Debbie Weighill, and using ORNL's high-performance computing resources, Tuskan's team is now completing these analyses in as little as a few hours.

The team's next major steps are twofold. First, they are testing the top 17 of the 1,000 sequenced genome lines—which are being grown on agricultural quality land in West Virginia, Georgia, and Oregon—to determine the effects of local environment, geographic area, and the plants' own genes on sugar release and biofuel production. Second, the team is looking at methods for "stacking" genes to develop favorable combinations of various traits that provide greater improvements in sugar release.—*Wendy Hames*

BESC, Mascoma develop revolutionary microbe for biofuel production

Biofuels pioneer Mascoma, LLC, and DOE's BioEnergy Science Center (BESC) have developed a revolutionary strain of yeast that could help significantly accelerate the development of biofuels from nonfood plant matter. The approach could provide a pathway to eventual expansion of biofuels production beyond the current output limited to ethanol derived from corn.

C5 FUEL™, engineered by researchers at Mascoma and BESC, features fermentation and ethanol yields that set a new standard for conversion of biomass sugars from pretreated corn stover—the inedible portion of corn crops such as the stalk—converting up to 97% of the plant sugars into fuel.

Researchers announced that whereas conventional yeast leaves more than one-third of the biomass sugars unused in the form of xylose, Mascoma's C5 FUEL efficiently converts the xylose into ethanol, and does so in less than 48 hours. This success and continued efforts through BESC could go a long way toward reducing the cost of ethanol and increasing the number of commercial-level ethanol production plants.—*Ron Walli*

Pieces of a puzzle

Imaging capability will connect information across spatial, temporal, and chemical dimensions

Like the connection of puzzle pieces, science often is based on a collection of pieces joined to form a complete picture.

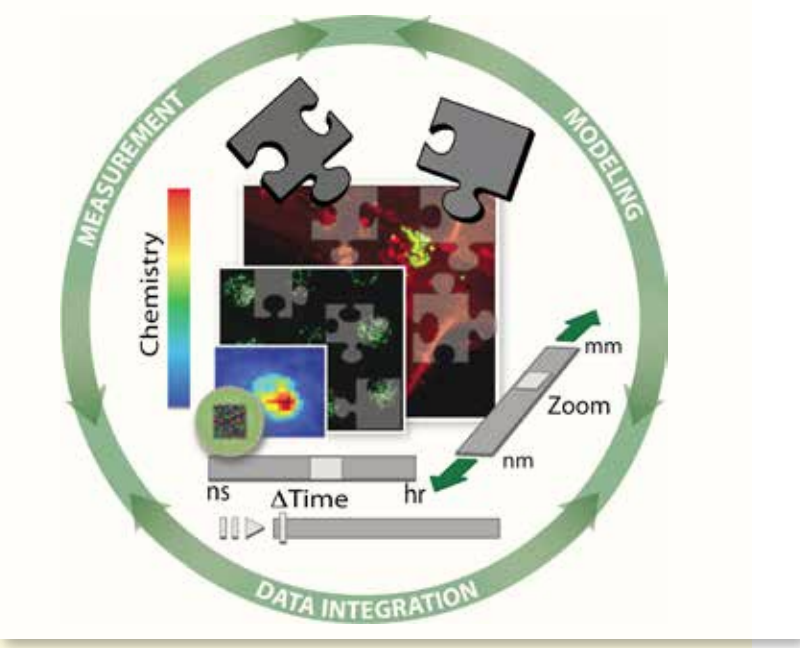
For the past year, Mitch Doktycz of the Biosciences Division (BSD) has led a collaboration to develop and apply an adaptive biosystems imaging (ABI) capability where computational modeling and simulation guide interactive molecular imaging measurements. The resulting capability will provide scientists with a deeper understanding—a bigger, more complete picture—of a diverse array of biological and environmental processes.

Although diverse tools are available to image biological systems, each provides only narrow windows of spatial, temporal, and chemical data and, by itself, no systems-level knowledge. Further, each tool is limited to the collection of information via specific measurements. Therefore, the key problem is how to assemble diverse data collected across multiple platforms, and over many orders of magnitude of length and time, into a coherent understanding of biological processes.

"We want to understand how a community of bacterial cells communicates with each other, and how they do that through exchange of small molecules, which is particularly challenging to trace and identify. A related challenge is understanding how that information is transferred across membranes, which are what holds the cell together," said Doktycz, a Distinguished Staff Scientist and leader of BSD's Biological and Nanoscale Systems Group.

"We're trying to connect molecular scale events to macroscale observational phenomena, and that is hard to do," Doktycz said, "because you cannot see all of it at once. I use the word 'see' because that's classically imaging, but really, imaging isn't always picture taking. There's no perfect microscope or picture-taking instrument to do that. We have to take information from multiple tools and put it together somehow, and that's where the simulation comes in. We use simulations to bridge the information."

The ABI project involves staff from BSD as well as two other ORNL directorates—Neutron Sciences and Computing and Computational Sciences. In addition to ORNL staff, the project team includes researchers from the University of Illinois, Urbana-Champaign; Harvard University; the University of Notre Dame; and the University of Tennessee, Knoxville.

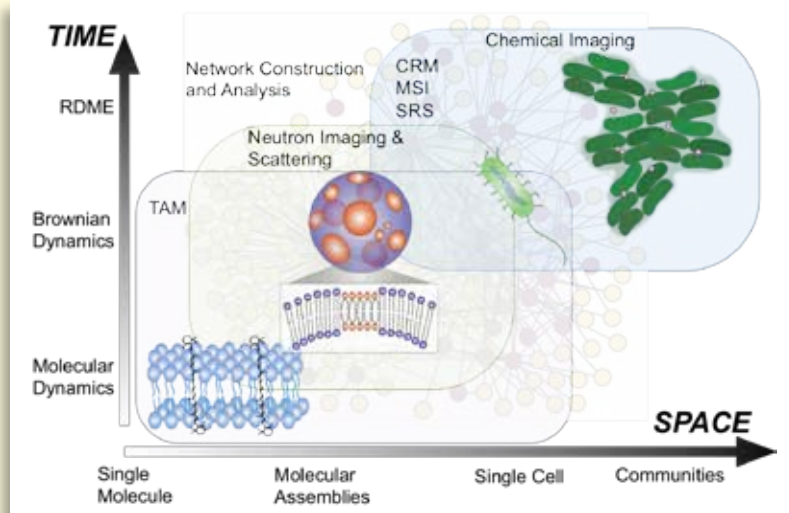


The adaptive biosystems imaging concept uses measurement, modeling, and data integration to effectively complete a puzzle—and help scientists better understand biological processes.

BSD's Jeremy Smith is the team's expert on the ORNL supercomputer Titan, and he is finding ways to make the best possible use of that key resource. "We could not do this research without Titan. What's possible with Titan and in the future with exascale computing is outstanding and mind-blowing," Doktycz said.

The Neutron Sciences Directorate's Volker Urban is leading the project's neutron components. The ABI project will use neutron scattering instruments at the High Flux Isotope Reactor and the Spallation Neutron Source to look at the structure and dynamics of membranes and devise a minimally perturbing labeling scheme. "You need to somehow 'see the needle in the haystack,' so to speak," Doktycz said. "So we need to come up with a way to label molecules in a cell.

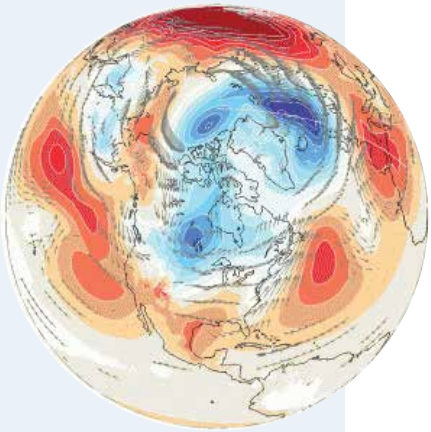
"These ideas and concepts have been around for a while. We've wanted to pursue them for a long time," he said. "What's upon us now are advances in technology that make adaptive biosystems imaging feasible, like our computational capabilities and our neutron sources. This wouldn't have been possible 10 years ago."—*Wendy Hames*



Techniques in the adaptive biosystems imaging project will include confocal Raman microscopy (CRM), mass spectrometry imaging (MSI), stimulated Raman scattering (SRS), transient absorption microscopy (TAM), and neutron scattering. These tools will be integrated with advanced computational modeling tools to predict, track, and link structure, molecular motion, and assembly to functional outcomes across length and time scales.

Update from the Climate Change Science Institute

Researchers at the Climate Change Science Institute (CCSI) are working to advance the knowledge of climate change and its consequences through a variety of research efforts. Following are updates on some of those projects.



A mapping of sea-level pressure (increasing from blue to red) overlaid with lower free atmosphere wind direction from a DOE and National Center for Atmospheric Research climate simulation. Image credit: Tianyu Jiang, ORNL.

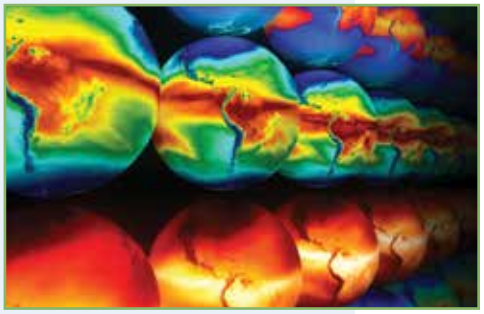
Accelerated Climate Modeling for Energy

CCSI researchers, led by ORNL lead investigator Peter Thornton, are collaborating with eight other DOE laboratories, the National Center for Atmospheric Research, four academic institutions, and one private-sector company on a 10-year project known as Accelerated Climate Modeling for Energy (ACME). The goal is to use DOE high-performance computing (HPC) resources to develop the most sophisticated Earth System Model for climate change research and energy applications.

ACME will provide new computing capabilities to scientists tasked with solving the nation's energy challenges. With more computing power, expectations for scientific discovery will increase significantly. The ACME project leverages DOE science investments to include new process understanding in climate models such as phosphorous cycling in tropical ecosystems, the influence of mountain ranges on temperature and precipitation, and soil microbial processes.

The ACME team will develop model codes that address key climate science questions, including those related to the water cycle, biogeochemistry, and cryosphere. Researchers also will simulate changes in river flow and other parts of the hydrological cycle by modeling interactions between precipitation and landscape within high-resolution, fully coupled atmosphere and land surface models to help determine how the water cycle will evolve in a warmer climate and change land and water use.

Throughout this year, CCSI researchers are playing key roles in the construction of the ACME Version 1 model. It will be deployed in 2016 to address critical science questions concerning hydrology, biogeochemistry, and the cryosphere.



These images show the distribution of water vapor, averaged monthly, from a high-resolution simulation of the Community Atmosphere Model.

Biogeochemistry Feedbacks Science Focus Area

As the complexity of Earth System Models increases, a comprehensive evaluation of model predictions is needed by those who use them to make decisions—a diverse group that includes farmers, city planners, and other policy makers.

This year, a new Science Focus Area (SFA), sponsored by the DOE Regional and Global Climate Modeling Program, is developing tools that systematically assess model accuracy and reduce uncertainties associated with predictions. The Biogeochemistry Feedbacks SFA will include not only terrestrial systems, but also marine ecosystems.

The goal is to create an open-source benchmarking tool for use by the climate science community to evaluate how models compare to observational data. The team is incorporating field and laboratory measurements to inform future model development and observational approaches.

Most members of the project team, which includes researchers from four DOE national laboratories and two universities, have contributed to the Community Earth System Model and the DOE Accelerated Climate Model for Energy. CCSI's Forrest Hoffman is the Biogeochemistry Feedbacks laboratory research manager. Through CCSI, the project team will have access to a combination of field, lab, and modeling expertise; internationally recognized environmental data centers; and large supercomputers.

Next-Generation Ecosystem Experiments—Arctic

Since 2010, CCSI researchers have led a team of national laboratories and universities in a large-scale observation and modeling project—Next-Generation Ecosystem Experiments (NGEE)–Arctic—to quantify the physical, chemical, and biological characteristics of the Arctic ecosystem to inform next-generation climate models. CCSI scientists travel to the Barrow Environmental Observatory in Alaska many times each year to conduct fieldwork.

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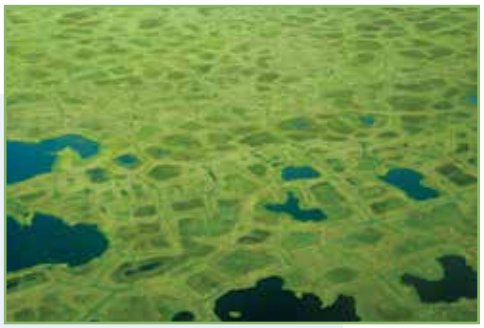


Polygon formations have been created in Alaska from permafrost freezing and thawing over hundreds of years.

Barrow's unique landscape is a pattern of polygon-like tiles that were created as seasonal permafrost froze and thawed repeatedly over hundreds of years because snow melt and soil temperature can vary across a single polygon. Last year, NGEE–Arctic researchers used HPC to simulate the present and future energy balance and the near-surface hydrology of the polygons at submeter resolutions, including snow distribution and the temperatures and depths of frozen and actively thawing layers.

To carry out controlled experiments on CO_2 and CH_4 (methane) release from thawing permafrost, researchers brought frozen core samples back from Alaska. In the lab, the team gradually warmed the samples using controlled-temperature chambers, emulating permafrost thaw at temperatures between 8°C and –2°C. In this study, CO_2 production occurred rapidly during thaw, whereas CH_4 production via methanogenesis (a part of microbial metabolism) lagged behind, only occurring at higher temperatures.

Based on these results, researchers suggest that the constant temperature coefficient—the rate of change of biochemical systems used in many climate models—does not accurately reflect the rate of methanogenesis in permafrost soils.

CCSI's Stan Wullschleger is the project's principal investigator.

El Yunque National Forest in Puerto Rico is serving as the first NGEE–Tropics research site in 2015.

Next-Generation Ecosystem Experiments—Tropics

A new NGEE initiative focused on the tropics is under way. CCSI scientists have begun a decade-long collaboration among DOE national laboratories and research institutions to develop a model structure that can determine whether tropical forests will act as net carbon sinks (absorbing more carbon than they release) through the 21st century. Measurements guided by model uncertainties began at the El Yunque National Forest in Puerto Rico and eventually will expand to multiple sites in the Americas, Africa, and Southeast Asia.

Understanding the tropical ecosystems that cover 40% of Earth's land surface is crucial to developing more advanced climate models. The tropics, and particularly vegetation-rich rainforests, are the globe's most powerful CO_2 regulators—taking in the gas through photosynthesis and releasing oxygen into to the atmosphere in large volumes, thereby serving an important role in the global carbon budget, as well as in global water and energy cycles.

To accurately predict how tropical regions will respond to increasing temperatures, changes in rainfall, drought and fire, increased atmospheric CO_2 concentrations, and land-use changes caused by human activity, models must account for the tropics' unique physical, ecological, and biogeochemical profiles.

CCSI's Richard Norby is the ORNL principal investigator and ORNL's representative on the project's executive committee.

Aerial image of Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) plots at northern Minnesota site.

Spruce and Peatland Responses Under Climatic and Environmental Change

Initiated in 2012, SPRUCE—Spruce and Peatland Responses Under Climatic and Environmental Change—is the first whole-ecosystem, forest-scale experiment to increase temperature and CO_2 concentrations by enclosing forest plots, from belowground soil to tree canopies.

SPRUCE is a collaboration among CCSI, the US Department of Agriculture Forest Service, and partnering universities. CCSI's Paul Hanson is the project coordinator and ORNL/UT-Battelle representative.

The decade-long experiment, under way in the black spruce peatland ecosystem of northern Minnesota, consists of 10 specially designed chambers that are 12 meters in diameter and outfitted with heating infrastructures for air and deep soil warming, as well as a range of biological and environmental monitoring sensors.

Climate scientists are interested in studying regions expected to be vulnerable to climate change in the coming decades. Peatland ecosystems—found across the globe's northern latitudes—are of particular interest because cold, damp peatland bogs sit atop massive stores of carbon that biodegrade into CO_2 and CH_4. Though shorter lived in the atmosphere than CO_2, CH_4 is a potent greenhouse gas, estimated to trap about 20 times more heat than atmospheric CO_2. Through large-scale field manipulations and carbon cycle observations, the SPRUCE team is studying the response of the peatland plots to manipulated climate conditions.—*Katie Elyce Jones and VJ Ewing*

ORNL's Shelby Cobra: Where is it now?

In the 7 months since its January debut at the 2015 North American International Auto Show in Detroit, ORNL's newest 3-D printed vehicle has drawn worldwide attention.

Printed at DOE's Manufacturing Demonstration Facility at ORNL using the Big Area Additive Manufacturing machine, the electric car pays homage to the classic Shelby Cobra in celebration of the racing car's 50th anniversary. It quickly became ORNL's most-watched video on YouTube, garnering over 200,000 views.

Following are a few of the Shelby Cobra's recent stops:

- Washington, DC: DOE Forrestal Building, where Secretary of Energy Ernest Moniz took it for a test drive, and the first-ever National Maker Faire, where it received the "Maker of Merit" award
- Knoxville, Tennessee: University of Tennessee's Orange and White spring football game and the Institute for Advanced Composites Manufacturing Innovation (IACMI) Inaugural Members Meeting
- Marysville, Ohio: Global Honda Additive Manufacturing Cooperative
- Baltimore: Society for the Advancement of Material and Process Engineering Conference
- Orlando: National Plastics Exhibition
- Houston: JEC Americas 2105 composites industry show and conference
- Dearborn, Michigan: IEEE Transportation Electrification Conference and Expo

MDF's upgraded BAAM is world's largest polymer 3-D printer

In partnership with CINCINNATI Incorporated, the Big Area Additive Manufacturing (BAAM) equipment at DOE's Manufacturing Demonstration Facility (MDF) at ORNL received a substantial upgrade this spring. The BAAM machine is now capable of printing parts as large as 8 × 8 × 20 feet, making it the largest 3-D polymer printer in the world. These new capabilities quickly surpassed the previous BAAM equipment that ORNL used to print the Shelby Cobra car in 2014.

The equipment upgrade is part of an ongoing partnership between ORNL and CINCINNATI that focuses on lowering the costs and increasing the speed of 3-D printing, creating workable alternatives for the seemingly endless applications for mainstream 3-D production manufacturing.

Lonnie Love, group leader for MDF's Manufacturing Systems Research Group, envisions the future of additive manufacturing to include not only automotive applications like the Shelby Cobra, but also large-scale tooling and lightweighting. "What we're trying to do is really industrialize this, but to do that, you've got to decrease the cost of 3-D printing and increase the speed," Love said.—*Brittany Piercy*

The upgraded Big Area Additive Manufacturing equipment at DOE's Manufacturing Demonstration Facility at ORNL.

ORNL announces 3-D printing CRADA

Atlanta-based American Process Inc. and ORNL recently signed a Cooperative Research and Development Agreement (CRADA) to improve the strength of three-dimensional (3-D) printed plastic resins using nanocellulose, a rapidly emerging, high-performance bioderived nanomaterial. The project's goal is to render 3-D printing technology suitable for producing load-bearing parts for industries including automotive and mold manufacturing—with strengths similar to metallic components such as aluminum and costs comparable to traditional materials.

American Process began production of a suite of BioPlus nanocellulose products in April at its plant in Thomaston, Georgia. ORNL will use the material to 3-D print a large-scale component on the Big Area Additive Manufacturing machine.

This research is supported by the Advanced Manufacturing Office in DOE's Office of Energy Efficiency and Renewable Energy.

Besides the agreement with American Process Inc., ORNL has launched several additional advanced manufacturing CRADAS with PiMeMs, Impossible Objects, Piedmont Propulsion, ExOne, and Magnum Venus Products.

Martin Keller, left, ORNL's associate laboratory director for energy and environmental sciences, signs the Memorandum of Understanding with Terry Taber, chief technology officer for Eastman Kodak.

Kodak, ORNL collaborate on roll-to-roll manufacturing

Eastman Kodak Company and ORNL signed an agreement in June to increase national competitiveness in roll-to-roll manufacturing and to transform new product development and manufacturing in the clean energy sector by connecting emerging companies with resources at ORNL and Kodak's Eastman Business Park (EBP).

The agreement also should spark the formation of high-tech entrepreneurial companies—and related high-skill jobs—at EBP, located in Rochester, New York.

The Memorandum of Understanding ceremony took place at EBP in front of a large crowd. US Rep. Louise Slaughter of New York and other officials attended. ORNL associate laboratory director for energy and environmental sciences Martin Keller signed the agreement alongside Terry Taber, Kodak's chief technology officer.

"Oak Ridge National Laboratory and Kodak's Eastman Business Park will provide a seamless support system for the generation of innovative technologies—from invention to evaluation to scale up to market-ready consumer product," Keller said.

Roll-to-roll technology allows manufacturers to boost efficiency, yields, and savings through continuous operation of production lines for coated products, including batteries, fuel cell electrodes, thin film solar cells, energy-saving window films, and flexible electronics such as touch screen sensors.

ORNL develops safer runway lighting

ORNL is developing a new airport and runway lighting technology to enhance visibility for pilots during takeoffs and landings.

According to Roger Kisner of the Electrical and Electronics Systems Research Division, researchers from his division and the Physical Sciences Directorate (PSD) are collaborating to develop a replacement for lighting on runways, approach towers, and taxiways. Incandescent bulbs, an older and relatively inefficient technology, supply existing airport lighting. A move toward light-emitting diodes (LEDs) has been the trend, but this lighting does not produce the near- to mid-infrared emissions required by the onboard high-resolution infrared cameras used by many cargo and military aircraft during landing.

The ORNL solution supplements visible LED lights with mid-infrared emissions generated by heating to incandescence a unique graphite foam disk developed by PSD's James Klett. Kisner's group is developing the induction heating system for the graphite foam emitter. The system must operate from 120 volt alternating current line power, require a small footprint, and deliver infrared emissions inexpensively, efficiently, and reliably. An early prototype developed last year is operating at the Federal Express hub located at Memphis International Airport. Camera systems at the tower and on FedEx aircraft have continuously monitored the prototype's lighting output since January.

"We have cut the power usage from 150 watts to around 50, so that can be a direct correlation in power savings," Klett said. "Real savings is being seen in the ability to keep flight schedules during bad weather, instead of having to stretch out landings from one every minute to one every 2 or 3 minutes."—*Wendy Hames*

Anger camera solution implemented at SNS

A yearlong project to enhance the operation of Anger cameras at ORNL's Spallation Neutron Source (SNS) has yielded a solution that improves operational reliability. Miljko Bobrek of EESD's Electrical and Electronics Systems Research Division designed an algorithm for position calculation for the Anger cameras that has been deployed on SNS's Macromolecular Neutron Diffractometer (MaNDi) instrument.

In October 2014, Bobrek and the Research Accelerator Division's Instrument Data Acquisition and Controls Group successfully installed and demonstrated the solution—a firmware-based algorithm running on a field-programmable gate array as part of the data acquisition electronics on MaNDi's approximately 30 Anger cameras. Bobrek's solution eventually will be applied to two other SNS instruments that use Anger camera detectors.

At SNS, Anger cameras—imaging cameras developed by scientist Hal Anger in the 1950s—are used for neutron diffraction measurements. The neutrons, scattered by the research sample, interact with a scintillator to produce photons that are imaged by the Anger camera.

Previously, a software algorithm calculated the neutron scattering angle and energy from the Anger camera's output. With Bobrek's firmware-based algorithm, the calculation can now be done in hardware. "The new algorithm increased efficiency by 10 times or more" in the data transfer through the acquisition system, according to Bobrek.

The detector now can support higher data rates for larger or more highly scattering samples. In addition, moving the calculation from software to real-time hardware makes detector performance more predictable and reliable, improving the instrument's value for scientific research.—*Wendy Hames*

ORNL developing gas centrifuges for stable isotope enrichment

Researchers from EESD and other ORNL directorates are collaborating on the development of small gas centrifuges for enriching stable (nonradioactive) isotopes for industrial and medical purposes.

"ORNL has expertise in critical technology areas for centrifuge analysis, design, operation, and manufacturing," said Brian Damiano, group leader for the Electro-Mechanical Systems Analysis and Simulation Group in EESD's Electrical and Electronics Systems Research Division.

In the past several years, centrifuge work has migrated from supporting the former Cooperative Research and Development Agreement (CRADA) with USEC Inc. to this new R&D project to enrich stable isotopes. "ORNL's experience in developing gas centrifuges for uranium enrichment while supporting the USEC CRADA and, before that, DOE's Centrifuge Enrichment Project of the 1980s, uniquely positions ORNL to develop gas centrifuges for stable isotope enrichment for medical and industrial purposes," Damiano added.

Medical isotopes are small quantities of radioactive atoms with multiple uses in health care, such as nuclear medicine imaging, positron emission tomography (PET) procedures, osteoporosis detection, and treatment of diseases, particularly cancer. Industrial uses for isotopes include smoke detection, airline luggage screening, product sterilization, measurement, and other applications.

Basic centrifuge technology relies on the centrifugal forces produced by high-speed rotation to concentrate gases introduced into the interior of the spinning centrifuge rotor in a thin layer next to the inner rotor wall. Gas molecules containing the heavier isotope will be closer to the wall than those containing the lighter isotope; precisely positioned scoops preferentially remove the heavier and lighter gas molecules.

A prototype stable isotope gas centrifuge rotor has been designed, fabricated, and successfully run to operating speed in a mechanical test stand. Current efforts focus on demonstrating the ability of this rotor to separate isotopes of molybdenum before beginning the fabrication of a small pilot cascade.

Alexander staffers visit MaxLab

Staff from Senator Lamar Alexander's office visited ORNL on his behalf in April to learn more about the lab's research in grid modernization. Tom King of the Electrical and Electronics Systems Research Division presented ORNL's research on grid modernization, resiliency, and security. King discussed the national impact of a frequency disturbance caused by a nuclear power plant trip in Maryland that had created outages throughout Washington, DC, just hours before the Alexander staffers arrived at MaxLab.

Mark Buckner, Phil Irminger, Yilu Liu, and other Power and Energy Systems Group staff used the new Visualization Lab (power wall) in MaxLab to present overview materials of ORNL's power systems programs while simultaneously displaying real-time national GridEye data and real-time control data for the Distributed Energy Control and Communication microgrid. The GridEye monitoring system detected the Washington, DC, power outage, and its resulting data was provided to DOE.

ORNL, Dow evaluate energy-saving building sealant

Building technology researchers at ORNL recently collaborated with Dow to evaluate a new Dow product that significantly reduces air leakage and helps to make residential and commercial buildings more energy efficient. The LIQUIDARMOR™–CM Flashing and Sealant was patented and introduced to the US market in 2014. It is a one-step liquid flashing that can be brushed or sprayed on surfaces to seal gaps, cracks, and seams in a building envelope, and it is especially effective on rough openings where windows and doors are installed.

The elastomeric—or rubbery—liquid adheres well to most substrates, even as buildings settle or adjust to wind pressures and changes in temperature. Additionally, its water-based acrylic formula significantly decreases workers' exposure to volatile organic compounds (VOCs) and reduces VOC emissions into the atmosphere.

Researchers evaluated the sealant's effectiveness by using ORNL's Heat, Air, and Moisture (HAM) Penetration chamber that measures the impact that various environmental conditions have on wall assemblies treated with LIQUIDARMOR. The HAM chamber—the only apparatus of its kind—simulates indoor temperatures of 60–90°F and outdoor temperatures of 0–110°F. Additionally, the chamber can subject walls to 10 to 90% relative humidity and other outdoor conditions such as rain, solar radiation, and wind and wind gusts.

A liquid flashing product invented by Dow and evaluated at ORNL can be brushed or sprayed on surfaces to seal gaps, cracks, and seams to improve a building's energy efficiency. Image credit: Dow Chemical.

The DOE Building Technologies Office sponsored the ORNL–Dow collaboration through the US–China Clean Energy Research Center for Building Energy Efficiency. Widespread opportunities for use of LIQUIDARMOR exist in China because construction practices there include minimal building envelope air sealing.—*Marlene Taylor*

Researchers develop high-performance cold-climate multi-stage heat pump

EESD researchers Bo Shen and Omar Abdelaziz, working with Cooperative Research and Development Agreement partners Emerson Technologies and Unico, have developed a high-performance cold-climate multi-stage heat pump capable of operating at temperatures as low as –13°F, with a heating capacity greater than 75% of the rated capacity. Using a Rheem 5 ton heat pump, they modified the unit's control board to operate two single-stage tandem compressors from Copeland, which were optimized for heating mode. The unit has a heating season performance factor (HSPF) of 11.

In January, the unit was shipped to Sydney, Ohio, and installed for evaluation in a residential home with a design cooling capacity of 3 tons. The unit operated flawlessly during the 2015 winter months, even when the temperature dipped to –12°F. During that period, there was no need for backup heating in the home, confirming the unit as a highly energy-efficient heat source. The home's occupants stated that they were very comfortable during the colder days.

The next prototype in production is a heat pump with two equal-size vapor injection compressors; it will be field tested in Fairbanks, Alaska.—*Marlene Taylor*

ORNL signs agreement with Whirlpool Corp. to develop new energy efficient refrigerator

ORNL and Whirlpool Corporation are collaborating to design a refrigerator that could cut energy use by up to 40% compared with current models.

The goal of the Cooperative Research and Development Agreement is to make a next-generation household refrigerator more energy efficient by using WISEMOTION, an innovative linear compressor manufactured by Embraco, and other novel technologies and materials. The DOE Building Technologies Office is supporting the 3 year project.

In the 1970s, the average refrigerator used approximately 4–5 kilowatt-hours per day; today's models average about 1.5 kilowatt-hours per day. The result is massive utility savings for consumers. ORNL and Whirlpool plan to build on the innovations that resulted in those energy savings; their goal is to build a refrigerator that consumes less than 1 kilowatt-hour per day.

"If every refrigerator in the US were replaced with the advanced refrigerator design, the projected primary energy savings would be 0.56 quads per year—the equivalent of 100 million barrels of oil," said Building Technologies Research and Integration Center director Ed Vineyard. —*Morgan McCorkle*

ORNL's Pradeep Bansal examines an Embraco linear compressor, which will be used in a Whirlpool–ORNL project aimed at building a more energy-efficient refrigerator.

Small businesses can gain access to ORNL resources such as the Manufacturing Demonstration Facility through a new DOE voucher pilot.

Pilot program to help small businesses tap ORNL expertise

ORNL is among five national laboratories selected to participate in a new DOE small business voucher program that aims to connect small businesses in the clean energy industry with technical experts and world-class facilities at the national labs.

DOE's Office of Energy Efficiency and Renewable Energy is funding the $20 million pilot as part of its National Laboratory Impact Initiative. ORNL will receive $5.6 million to conduct outreach, merit review, matchmaking, and voucher implementation.

"Through this program, we will help small businesses achieve their goals of developing innovative, energy-efficient products and being more competitive in the marketplace, particularly in manufacturing, building, and vehicle technologies," said Johney Green, director of the Energy and Transportation Science Division.

Under the pilot program, companies will have access to unique equipment and expertise at ORNL facilities such as EESD's Manufacturing Demonstration Facility, the National Transportation Research Center, and the Building Technologies Research and Integration Center.—*Morgan McCorkle*

BTRIC workshop explores energy-efficient architecture

The Building Technologies Research and Integration Center (BTRIC) hosted about 100 industry representatives, researchers, building owners, and other stakeholders at the Building Technologies Office Envelope Stakeholders Workshop in May.

Attendees identified existing and potential barriers for energy-efficient envelope technologies, reviewed market-ready applications for new and existing commercial buildings, and discussed DOE's strategic research on high-performance envelope solutions for residential buildings.

The workshop was geared toward participants who conduct research; develop products; or use materials to construct a building's envelope, which includes walls, windows, roofs, and foundations. Tours included the BTRIC user facility and the Manufacturing Demonstration Facility.—*Sara Shoemaker and Heidi Hill*

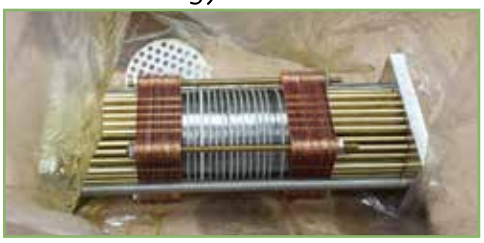
ORNL to lead one, participate in two projects on non-vapor compression technology research

ORNL will lead or participate in three projects through a funding opportunity announcement awarded by the DOE Building Technologies Office. Each R&D project is focused on the advancement of next-generation heating, ventilating, and air-conditioning technologies. They support DOE's goal of developing cost-effective, energy-efficient technologies that also reduce the use of chemicals that have a negative effect on the global climate.

ORNL will receive about $1.4 million to develop a novel magnetocaloric air conditioner with the potential for efficiency improvements of up to 25% over conventional vapor compression systems, equivalent to saving 1 quad of energy annually for space heating and cooling in the US residential sector. A magnetocaloric system moves copper, brass, or aluminum rods into and out of a magnetic field. The temperature of the rods transfers heat to and from a magnetic regenerative bed, the temperature of which changes as the magnetic field changes. The heat is transferred through forced air at both ends of the magnetic regenerator.

In partnership with Dais Analytic (Odessa, Florida), ORNL will work on a $1.2 million project to advance a membrane HVAC technology that will use nanostructured polymer materials (membranes) to manipulate water molecules, allowing the system to condition air while improving energy efficiency and eliminating the need for fluorocarbon refrigerants. The project will result in a rooftop-capable system for field evaluation.

With Xergy Inc. (Seaford, Delaware), ORNL will participate in a $1.4 million project to develop electrochemical compression (ECC) technology in combination with an energy recovery module to replace traditional electromechanical compressors for use in heat pumps. ECC uses fuel cell technology to enable heat pumps to use water as the refrigerant. The project seeks to produce a prototype unit with the potential to achieve a payback period of 5 or fewer years when produced at commercial scale.



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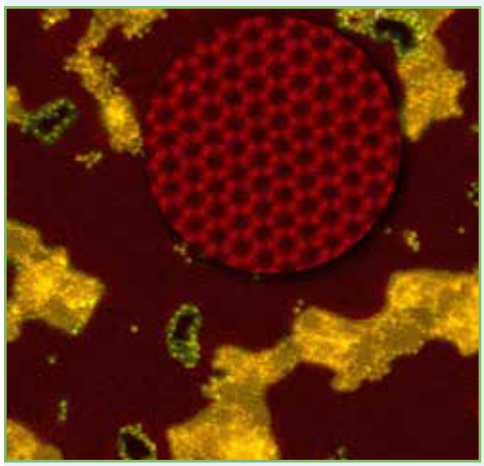


Researchers created nanopores in graphene (enlarged in the red circle to highlight the honeycomb structure) that are stabilized with silicon atoms (yellow), enabling the membrane to desalinate seawater.

Graphene research results in two major papers

Staff members from the Energy and Transportation Science Division (ETSD) are among a group of researchers working to develop new applications for graphene, which is stronger and stiffer than carbon fiber and has enormous commercial potential. These researchers recently published two major papers on their work.

A *Nature Nanotechnology* paper titled "Water Desalination Using Nanoporous Single-Layer Graphene" discusses the problem of limited drinkable water on Earth. Removing salt and other minerals from the biggest available source of water—seawater—may help satisfy a growing global population need, but desalination traditionally has been an energy-intensive process. However, researchers have demonstrated an energy-efficient process using a porous graphene.

Holes added to a graphene mesh are the right size for water molecules to penetrate. Salt ions are larger than water molecules and cannot cross the membrane. The porous membrane allows osmosis, or passage of a fluid through a semipermeable membrane, into a solution in which the solvent is more concentrated.

Authors are ETSD's Ivan Vlassiouk; Physical Sciences Directorate staff members Shannon Mahurin, Sheng Dai, Raymond Unocic, and Gabriel Veith; former ORNL post-doc Sumedh Surwade; and New Mexico State University's Sergei Smirnov.

While most approaches for polymer nanocomposition construction employ tiny flakes of graphene or other carbon nanomaterials that are difficult to disperse in the polymer, Vlassiouk's team used larger sheets of graphene for their research, published in *Applied Materials & Interfaces*. The article, "Strong and Electrically Conductive Graphene Based Composite Fibers and Laminates," explains how chemical vapor deposition enabled the team to fabricate polymer composites containing 2-inch-by-2-inch sheets of the one-atom-thick hexagonally arranged carbon atoms. This eliminates flake dispersion and agglomeration problems and allows the material to better conduct electricity with less graphene in the polymer.

The findings could help usher in a new era in flexible electronics and change the way this reinforcing material is viewed and ultimately used. Authors are ETSD's Vlassiouk, Georgios Polyzos, and Panos Datskos; Ryan Cooper, Ilia Ivanov, Jong Kahk Keum, and Felix Paulauskas, also from ORNL; and New Mexico State's Smirnov.—*Ron Walli and Dawn Levy*

New catalyst effective at low temperatures without precious metals

As new technologies increase engine efficiency, more of the heat generated during combustion is being used to generate power and less escapes through exhaust. This creates a critical need for catalysts that can control emissions at much lower temperatures (150°C vs. the more typical 300–800°C).

A team of researchers led by Jim Parks and Todd Toops of ORNL's Fuels, Engines, and Emissions Research Center (FEERC) has developed a new low-cost, low-temperature catalyst composed of copper oxide, cobalt oxide, and cerium oxide, dubbed CCC.

The new catalyst shows great promise in overcoming the problem of inhibition, in which nitrogen oxides (NO_x), carbon monoxide (CO), and hydrocarbons block the active sites on a catalyst and limit its function.

Toops noted that the unique CCC formulation builds on work by colleagues Andrew Binder, Steve Overbury, and Sheng Dai, which was funded through DOE Basic Energy Sciences (BES). The BES team varied the composition of the three catalyst components in search of improved oxidation of CO.

When the FEERC team studied CCC in the complex simulated exhaust environment with three pollutants—NO_x, CO, and hydrocarbons—plus CO_2 and water, the various pollutants interacted with different sections of the three-part catalyst. This behavior allowed the innovative CCC catalyst to outperform more common platinum-based catalysts for CO oxidation while showing no signs of inhibition by NO_x or the hydrocarbon propene.

Researcher Andrew Binder adjusts the temperature controls on the catalyst reactor used to make the catalyst composed of copper oxide, cobalt oxide, and cerium oxide.

The DOE Vehicle Technologies Office funds this research.—*Kim Askey*

Aqueous processing saves production costs for large-format lithium-ion batteries

Researcher Jianlin Li coats cathode material via aqueous processing for lithium-ion batteries.

A new process developed at ORNL that decreases the manufacturing cost of lithium-ion batteries (LIBs), which power electric and hybrid cars, could help put electric vehicles on the highways sooner and at a lower price.

Researchers David Wood, Jianlin Li, and Claus Daniel found that using water as the solvent to manufacture the electrodes, instead of the traditional solvent Nmethyl-2-pyrrolidone (NMP), not only is far less expensive but also eliminates NMP's toxic, flammable vapors and their costly recovery. Aqueous processing comes with another benefit—it emits less CO_2 into the atmosphere during battery production.

The economic difference is significant: NMP is more than $1.25 per liter, whereas deionized water is $0.015 per liter. By using water, the energy consumption associated with drying the electrodes is much less, too. This newly patented process is estimated to reduce the full battery pack cost by 8–10%, a sizeable decrease in production costs.

ORNL tackled the science and engineering challenges of applying aqueous processing to the diverse array of LIB cathodes by selecting appropriate water-soluble binders and mixing sequences, developing stable and uniform slurries, improving electrode coating deposition, and optimizing drying procedures.

With support from the DOE Vehicle Technologies Office, the ORNL team is continuing research on novel design architectures that will best enable the production of high-performance batteries made with aqueous processing.—*Kim Askey*

ORNL supports sustainable production of algal biofuels

Researchers have identified 16 environmental indicators for the sustainable production of algal biofuels. The study highlights the differences in harvesting and biofuel production processes for tiny, aquatic algal organisms versus more traditional terrestrial feedstocks.

Factors such as water quality and quantity were given priority over soil-related measures. Socioeconomic indicators are currently in development. These metrics can be used to create best practice recommendations and guide technology developments for the growing algal biofuel industry.

"We hope national and international sustainability organizations adopt these indicators," said Environmental Sciences Division researcher Rebecca Efroymson. "Most of these organizations have not turned their attention to algae yet."

This research is funded by the DOE Bioenergy Technologies Office.—*Kim Askey*

ESD research is basis for new chemical warfare agent clearance guidelines

Chemical warfare agent clearance criteria developed by Environmental Sciences Directorate (ESD) scientists and colleagues are the basis for recently developed California and US Department of Defense (DOD) decontamination guidelines.

For more than 20 years, ESD staff scientists have applied their expertise to the development of chemical warfare agent exposure guidelines to help ensure the safety of the US Army's chemical demilitarization and environmental restoration initiatives. Following the September 11, 2001, terrorist attacks, their work became even more important. The US Department of Homeland Security Science and Technology Directorate, Chemical and Biological Defense Division, enlisted ESD technical support for developing criteria to guide facility cleanup and restoration in the event of a chemical terrorist attack in a public setting, such as an international airport.

Under the leadership of task coordinator Annetta Watson, ESD staff members have worked in collaboration with colleagues in the US Army Public Health Command, University of Tennessee–Knoxville, Lawrence Livermore National Laboratory, California Environmental Protection Agency (EPA), California Department of Public Health, and the US Army Environmental Center.

Their work culminated in the first set of state-based chemical warfare agent clearance criteria, endorsed by the California EPA and the California Public Health Department in 2011. In August 2014, DOD released its agency-wide guidance policy memo, "Chemical Clearance Guidelines for Platforms and Materiel." DOD considered the California initiative—as well other previously published agent-specific exposure criteria generated by ESD—as critical elements to its new guidance, which is designed to ensure that decontaminated assets represent no health risk to unprotected personnel or the general population. The new clearance guidelines establish concentration limits for clearance of equipment and vehicles, including military aircraft and vessels formerly or potentially contaminated with specific nerve or sulfur mustard chemical warfare agents.

DOD plans to apply the ESD research as the basis for comparable exposure criteria for acutely toxic industrial chemicals, such as chlorine, hydrogen sulfide, and other industrial compounds used by DOD personnel every day.

FEMP reviews ORNL efforts

ORNL welcomed Timothy Unruh, director of DOE's Federal Energy Management Program (FEMP), as part of a 2 day program review of ORNL's support of FEMP in energy savings performance contracts. FEMP's Skye Schell and Kurmit Rockwell also attended. ORNL supports FEMP performance contracting efforts through data analysis, project development at agency sites, energy audit and benchmarking tool sets, agency training, and institution behavioral change research.—*Marlene Taylor*

Freightliner SuperTruck demonstrates 115% freight efficiency gain

As a member of the Freightliner SuperTruck team, ORNL assisted with simulation and evaluation of the SuperTruck's waste heat recovery system. Parent company Daimler Trucks North America measured freight efficiency by evaluating the SuperTruck on highway routes in Oregon and Texas and through anti-idle testing in both cold and hot chambers.

The SuperTruck initiative is managed by the 21st Century Truck Partnership, which set an aggressive goal for freight efficiency gains of 50%. Through a host of innovations in aerodynamics, engine efficiency, lightweighting, waste heat recovery, and hybrid powertrain integration, the Freightliner SuperTruck surpassed the goal by 65%.

An ORNL team led by Energy and Transportation Science Division's Dean Edwards conducts ongoing research with Daimler focused on advanced combustion strategies, including dual-fuel operation with diesel and natural gas.—*Kim Askey*

Early career researchers are developing the future of clean energy

EESD employs many scientists and engineers in the early years of their careers. Here are just a few early career researchers who are already making great strides in their research disciplines.

Diana Hun

- R&D staff in the Building Envelope Research Group
- PhD in civil engineering from the University of Texas at Austin, 2010

Diana's research focuses on improving the airtightness of buildings while minimizing risks from building material deterioration and indoor air quality problems. She currently is assessing the performance of air barrier technologies, studying the optimization of building energy demands and indoor air quality, and evaluating the moisture durability of energy-efficient walls. Diana recently presented to Secretary of Energy Ernest Moniz highlights from the US–China Clean Energy Research Center–Building Energy Efficiency Consortium, where she discussed air sealing technologies developed in partnership with Dow Chemical and 3M. She also explained how these technologies will be implemented in China.

Jerry Parks

- R&D staff in the Biosciences Division and a member of the University of Tennessee/ORNL Center for Molecular Biophysics
- PhD in chemistry from Duke University, 2008

Jerry is working on a National Institutes of Health–funded project aimed at discovering and developing inhibitors of bacterial efflux pumps, complex biomolecular assemblies that contribute to antibiotic resistance. Jerry and his colleagues are using the Titan supercomputer to dock libraries of molecules to various components of the pump with the goal of discovering molecules that can disrupt the assembly of the pumps. Such a molecule could, in principle, be coadministered with an antibiotic to restore its activity. Jerry's major work at ORNL involves projects associated with the Mercury Scientific Focus Area Program, and his expertise is in computational chemistry and biophysics.

Brian Post

- R&D staff in the Manufacturing Systems Research group
- PhD in mechanical engineering from Georgia Tech, 2013

Brian was a member of the team that printed the world's first three-dimensional (3-D) printed car—the Strati—with corporate partners CINCINNATI Inc. and Local Motors, and the 3-D printed ORNL Shelby Cobra, a partnership between DOE's Offices of Advanced Manufacturing and Vehicle Technologies. His research includes the development of large-scale additive manufacturing processes capable of producing large parts (up to 8 × 20 × 6 feet) at rates a thousand times faster than the rates of current commercially available systems. He also is working on using additive manufacturing systems to develop novel robotic technologies, including underwater manipulation and prosthetic applications.

Jim Szybist

- Senior research scientist in the Fuels and Engines Research Group
- PhD in fuel science from Penn State, 2005

In April, Jim received the Harry L. Horning Award from the Society of Automotive Engineers for the best paper relating to the mutual adaptation of fuels and engines. Titled "The Impact of Low Octane Hydrocarbon Blending Streams on the Knock Limit of E85," the paper helped build the foundation for an active debate regarding the best use of ethanol for fuel in the United States and the octane number of future gasoline fuels. Jim's research is focused on how fuel properties can enable higher-efficiency operating strategies in internal combustion engines, particularly fuel properties of biofuels. His particular focus currently is fuel effects for dilute and reformate-assisted combustion.

Virginia Dale

Keith Kline

Researchers contribute to major bioenergy and sustainability report

A major report on bioenergy and sustainability released recently concludes that the sustainable production of bioenergy can be an important tool for addressing climate change. Environmental Sciences Division researchers Virginia Dale and Keith Kline contributed to the multinational United Nations (UN) document.

Kline contributed to a chapter on land use for the UN Scientific Committee on Problems of the Environment (SCOPE) *Bioenergy & Sustainability* report. The chapter explores the subject of biomass and food crop production, concluding that the two can coexist or be complementary. Projected land demands for biofuel production fall well within conservative estimates of current and future land availability, and integrated systems for food and energy production can improve food security.

Dale coauthored a chapter on biodiversity and ecosystem services. "Deploying biofuels in a manner to reduce effects on biodiversity and associated ecosystem services can be done with planning, monitoring, and appropriate governance," she said.

The SCOPE *Bioenergy & Sustainability* report is the collective effort of 137 researchers at 82 institutions in 24 countries; it documents and analyzes impacts, benefits, and constraints related to the global expansion of bioenergy. The report is available at http://bioenfapesp.org/scopebioenergy/index.php.

The work was supported by the DOE Bioenergy Technologies Office.—*Bill Cabage*

EESD researchers patent new research tech, tools

Congratulations to a number of EESD researchers who, either individually or as part of larger teams, have been awarded the following patents in recent months:

"Sintered Silver Joints via Controlled Topography of Electronic Packaging Subcomponents," US Patent 8,822,036. EESD inventor is Andrew Wereszczak.

"Forming Gas Treatment of Lithium Ion Battery Anode Graphite Powders," US Patent 8,834,829. EESD inventor is David Wood III.

"Methods for Separating Medical Isotopes Using Ionic Liquids," US Patent 8,865,094. EESD inventor is Huimin Luo.

"Microorganisms Having Enhanced Resistance to Acetate and Related Compositions and Methods of Use," US Patent 8,865,440. EESD inventors are Steven Brown and Shihui Yang.

"Methods for Promoting Wound Healing and Muscle Regeneration with the Cell Signaling Protein Nell1," US Patent 8,877,176. EESD inventor is Cymbeline Culiat.

"Manufacture of Thermoelectric Generator Structures by Fiber Drawing," US Patent 8,889,454. EESD inventors are David West, Timothy McIntyre, and John Simpson.

"Reflective Echo Tomographic Imaging Using Acoustic Beams," US Patent 8,894,580. EESD inventors are Roger Kisner and H. J. Santos Villalobos.

"Increasing Ion Sorption and Desorption Rates of Conductive Electrodes," US Patent 8,920,622. EESD inventor is Costas Tsouris.

"Generation of Monodisperse Droplets by Shape-Induced Shear and Interfacial Controlled Fusion of Individual Droplets On-Demand," US Patent 8,944,083. EESD inventor is Scott Retterer.

"Nano-Material and Method of Fabrication," US Patent 8,945,691. EESD inventor is Wei Wang.

"Freeform Fluidics," US Patent 8,951,303. EESD inventors are Lonnie Love, Randall Lind, William Peter, and Bradley Richardson.

"Frontal View Reconstruction for Iris Recognition," US Patent 8,958,608. EESD inventors are H. J. Santos Villalobos, Christopher Boehnen, and David Bolme.

"Composite Materials Formed with Anchored Nanostructure," US Patent 8,974,719. EESD inventor is Wei Wang.

"Zeolite-Based SCR Catalysts and their Use in Diesel Engine Emission Treatment," US Patent 8,987,161. EESD inventors are Chaitanya Narula and Xiaofan Yang.

"Hydrothermally Stable, Low-Temperature NO_x Reduction NH_3-SCR Catalyst," US Patent 8,987,162. EESD inventors are Chaitanya Narula and Xiaofan Yang.

"Nanomechanical Electric and Electromagnetic Field Sensor," US Patent 8,988,061. EESD inventor is Panagiotis Datskos.

"EGR Distribution and Fluctuation Probe Based on CO_2 Measurements," US Patent 9,000,374. EESD inventors are W. Partridge Jr. and James Parks II.

"Method of Synthesizing Bulk Transition Metal Carbide, Nitride, and Phosphide Catalyst," US Patent 9,012,349. EESD inventor is Jae Choi.

"Smart Smoke Alarm," US Patent 9,019,109. EESD inventors are Robert Warmack and Steven Frank.

During his April visit to ORNL, David Danielson, DOE Assistant Secretary for Energy Efficiency and Renewable Energy, recognized eight lab researchers for their "success stories," including six EESD staff members. From the Electrical and Electronics Systems Research Division, Madhu Chinthavali was recognized for power converter development that includes three-dimensional printed heat sinks and wide-bandgap semiconductors and Gui-Jia Su was recognized for power converter technologies for electric vehicles. Four Energy and Transportation Science Division staff members were recognized: Lonnie Love, for being an advanced manufacturing "rock star"; Ayyoub Momen, for work with industry on development of a magnetocaloric refrigerator and ultrasonic dryer; Bill Partridge, for a partnership with Cummins that exceeded a fuel savings goal of 50% by 65%; and Ed Vineyard, for a career that has included 20 Cooperative Research and Development Agreements worth $75 million. **Pictured: front row—Vineyard, Momen, Partridge, and Su; back row—Zhili Feng (Physical Sciences Directorate honoree), Danielson, Love, Teja Kuruganti (Computing and Computational Sciences Directorate honoree), Laboratory director Thom Mason, DOE's Building Technologies Office director Roland Risser, Chinthavali, and DOE Advanced Manufacturing Office director Mark Johnson.**

Scott Curran, Energy and Transportation Science Division, received the Society of Automotive Engineers (SAE) 2015 Stefan Pischinger Young Industry Leadership Award at the recent SAE Foundation Annual Celebration in Detroit. Pictured are (left to right) Mazen Hammoud, chairman of the SAE Foundation Board and chief engineer, Powertrain Electrification, Ford Motor Company; Curran; and Patrick Hupperich, president and chief executive officer of FEV North America Inc.

Bob Bowman, Energy and Transportation Science Division, was recognized by DOE's Hydrogen and Fuel Cells Program for outstanding dedication and achievements in hydrogen storage material R&D. He was cited particularly for the design and development of a metal hydride cryocooler that flew for 4 years aboard the European Space Agency's Planck mission to map the cosmic microwave background.

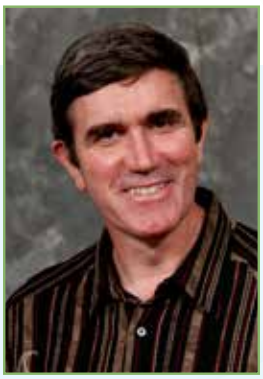
The Power Electronics and Electric Machinery Group's 3-D printed inverter team recently received a 2015 DOE Vehicle Technologies Office Distinguished Achievement Award for demonstrating a first-of-its-kind 3-D printed electric drive inverter incorporating wide bandgap devices and advanced packaging techniques. PEEM's research testing of electric motors and feedback for future design efforts also was involved in a 2015 DOE Vehicle Technologies Office Distinguished Achievement Award for developing and patenting a new non-rare earth magnet motor for electric vehicles, which went to the UQM Motor Design team. Pictured here, team members **Burak Ozpineci** (left) and **Madhu Chinthavali** of the Electrical and Electronics Systems Research Division accepted the award.

Melanie Mayes, Environmental Sciences Division, has been named one of 20 finalists in this year's YWCA Tribute to Women, which honors East Tennessee–area women for professional achievements and contributions to the community. The 31st annual YWCA Knoxville celebration will take place in September. A native of rural Missouri, Mayes was recognized as a first-generation college student who is an inspiration to women from rural or disadvantaged backgrounds. She holds an MS and a PhD in geological sciences from the University of Tennessee, where she also serves as an adjunct professor in the Earth and Planetary Science Department, in addition to her role as a staff scientist and team leader at ORNL.

Energy and Transportation Science Division's **Robert Wagner** coedited—with Todd Fansler of the University of Wisconsin—a special issue of the *Journal of Engine Research* on the topic of cyclic dispersion in internal combustion engines. The issue included an invited review paper titled "A Review of Deterministic Effects in Cyclic Variability of Internal Combustion Engines" led by Charles Finney of the Fuels, Engines and Emissions Research Center (FEERC), with additional FEERC authors Brian Kaul, Stuart Daw, Robert Wagner, Dean Edwards, and Johney Green.

Jerry Tuskan, Biosciences Division, was the keynote speaker at CROPS 2015 in Huntsville, Alabama, in May. CROPS 2015, hosted by the HudsonAlpha Institute for Biotechnology and the University of Georgia, is an international conference that brings together leading genomics researchers and plant breeders to explore emerging applications of genomic technology to crop improvement.

Lonnie Love, Energy and Transportation Science Division, has been named an ORNL Corporate Fellow, a designation recognizing significant accomplishments and continuing leadership in a scientific, engineering, or technological field. Love's recent research has focused on additive manufacturing, specifically large-scale and high-speed advanced manufacturing and three-dimensional printing.



Brian Davison, Biosciences Division, spoke on "The BioEnergy Science Center: An Integrated Strategy to Understand and Overcome Biomass Recalcitrance," at the February meeting of Friends of ORNL, a non-profit organization that connects ORNL staff and retirees.

Wellington Muchero, Biosciences Division, gave a presentation in March on "A Gene for Regulating Phenylpropanoid, Tryrosine, and Trypotophan Pathways" at the ORNL Partnerships Conference SPARK! Marketing event, which highlighted ORNL and University of Tennessee technologies.

Steve Brown, Biosciences Division, discussed "DNA Sequencing Technologies and their Impact on Molecular Biology" as part of a lecture series to Oak Ridge Institute for Continued Learning at Roane State Community College.

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A Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) chamber under construction in northern Minnesota. The 10 SPRUCE experimental chambers include belowground and aboveground warming infrastructures. Last summer, belowground heating (known as deep peat heating) was initiated in eight plots at four warming levels and a target depth of 2 meters. Belowground processes and microbial communities are now being monitored as part of the ongoing study. Once the team finishes installing the aboveground air-warming infrastructure, air-warming and increased CO_2 manipulation experiments will begin. Read more about this project on page 9.