NREL
National Renewable Energy Laboratory
Innovation for Our Energy Future

FY 2009
National Renewable Energy Laboratory
Annual Report

A Year of Energy Transformation

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Director's Perspective

The past year was one of great change for the energy industry. New technologies emerged, new companies entered a marketplace that was facing the challenges of a faltering economy, and President Obama brought a new emphasis on green jobs as a key component of economic recovery.

To carry that philosophy forward, the American Recovery and Reinvestment Act invested billions of dollars into the research, development, and infrastructure necessary for a clean energy economy, and these new federal funds continue to percolate through the U.S. economy. The president also launched a renewed effort to address climate change, an effort that will rely heavily on renewable energy and energy efficiency.

Director
Dan Arvizu

Efficiency and renewable energy are seen as pivotal players in addressing many of the top challenges facing our nation and the world as a whole: protecting the environment, achieving energy security, reducing petroleum dependence, creating new jobs, and generating the economic activity needed to help recover global economies. Addressing these challenges will require unprecedented change in the energy marketplace.

The era of clean energy has arrived, and the nation has turned to the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) for leadership in the new, sustainable energy economy.

In fiscal year (FY) 2009, the Alliance for Sustainable Energy, LLC began a five-year contract with DOE to manage and operate the laboratory. The Alliance is jointly owned by two organizations—the Midwest Research Institute and the Battelle Memorial Institute—and its leadership team at NREL has a fresh vision and strategy for amplifying NREL's impact on our nation's energy future as NREL pursues its mission of developing and deploying new renewable energy and energy efficiency technologies and practices.

This past year, NREL attracted a record number of leading scientists, engineers, and analysts to this mission, blending their considerable expertise and passion for the mission with state-of-the-art equipment housed in leading facilities. The Laboratory of the Future, which is taking shape now in the form of a reinvigorated NREL campus, will be a global model for sustainability. NREL has also put in place a number of new collaborations that strengthen the capabilities that can be brought to bear on the world's energy issues while educating the next generation of scientists, engineers, and analysts.

We know NREL can't do it all. Solving energy and environmental challenges requires global cooperation to share technical knowledge and talent across institutions and leverage resources. That's why NREL has significantly expanded its industrial partnerships, launched the Joint Institute for Strategic Energy Analysis and developed partnerships with government agencies around the world to deliver NREL knowledge on a broader scale. Through such large-scale efforts, NREL intends to drive the trans-formational change required to create a new energy future for our nation and the world.

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Upper inset photo: From left: NREL Director Dan E. Arvizu; Senior Vice President for Commercialization and Deployment Casey Porto; Deputy Laboratory Director for Science & Technology Robert McGrath; Deputy Laboratory Director and Chief Operating Officer William Glover; and Senior Vice President for Outreach, Planning and Analysis Bobi Garrett.

SCIENCE AND TECHNOLOGY

NREL's science and technology research ranges from basic research in chemistry, biosciences, materials, and computational science to applied research and engineering in a number of renewable energy fields such as solar, wind, and water power. Researchers are advancing new ideas for buildings, advanced vehicles, hydrogen energy and fuel cells, and technologies for producing fuels, chemicals, materials, and power from biomass. And the laboratory is leading the technical integration of renewable power systems with the nation's electrical grid.

SCIENCE AND TECHNOLOGY

NREL Research Accomplishments for 2009

In FY 2009, NREL researchers found ways to break new ground and reshape attitudes with their work. Whether it's an NREL report showing that solar power systems can connect to the grid without disruption, or an invention that enhances the whiteness and energy efficiency of LEDs, NREL's research impacts multiple disciplines.

Green LED Makes Highly Energy-Efficient White Light

An NREL team developed a light-emitting diode (LED) that produces a deep green light, filling a crucial gap in the creation of white-light LEDs.

LEDs are fundamentally solar cells operating in reverse, with an applied electrical signal inducing a thin-film semiconductor to produce a photon of light. LEDs are thought to be a key technology for producing a new generation of efficient lighting, but for now, white-light LEDs involve an inefficient process in which blue light is shifted to white with the use of phosphors, similar to the process used in fluorescent lamps. A more efficient process would mix red, blue, and green LEDs to make white light directly, but that approach has suffered due to a lack of high-quality deep green LEDs, a deficiency commonly referred to as the "green gap."

NREL's Angelo Mascarenhas, along with NREL researchers Lekhnath Bhusal and Myles Steiner, developed a deep green LED by depositing a layer of gallium indium phosphate on a substrate of gallium arsenide. The two materials have different lattice spacings in their crystalline structures, and the team is modifying the elemental composition of various layers in an attempt to control the distortion of atomic crystal lattice to create optimally colored light. This design could lead to low-cost, high-value LED lighting.

In August, the NREL team received $1.8 million in American Recovery and Reinvestment Act (Recovery Act) funds from the U.S. Department of Energy (DOE) to continue developing the device.

Black is the New Green When it Comes to Improving Silicon Solar Cells

Researchers in the National Center for Photovoltaics at NREL have successfully demonstrated so-called "black silicon" solar cells, which have been chemically etched to produce a textured surface that

Light-emitting diodes, or LEDs, are emerging as an efficient solid-state light source able to replace light bulbs in many applications. A new green LED from NREL may yield more efficient solid-state lighting.

appears black. Surfaces appear black when they are good at absorbing light, and obviously the better a solar cell is at absorbing light, the greater the opportunity it will have to convert that light into usable electricity. NREL's black silicon is actually vastly superior at absorbing light than ordinary silicon, due to a nanoporous density-graded layer that is created on the surface of the silicon. Using this approach, NREL was able to produce a silicon solar cell that converts 16.8% of the sunlight hitting it into electricity, achieving a 38% improvement over the baseline solar cell with no black silicon or other anti-reflection coating. It also marks a substantial improvement on the previous record for conversion efficiency in black-silicon solar cells, which was 13.9%.

However, the greatest impact of this new technology is not simply in the efficiency improvement it offers, but also the fact that these films are produced by a fast and inexpensive single-step liquid process. This obviates the need for the vacuum-based anti-reflection coating systems used in conventional silicon solar cell manufacturing, which are extremely expensive and slow. As a result, the black silicon process can significantly reduce both capital expenditures and operating expenses for silicon solar cell manufacturing.

New Tool Shows Promise for Quality Control in High-Rate Solar Cell Manufacturing

Researchers in the Process Development and Integration Laboratory, which is part of the National Center for Photovoltaics at NREL, have developed a new characterization tool that can be directly incorporated into high-rate solar cell manufacturing lines. This new tool can perform high-speed spectroscopic diffuse reflectance measurements, which can enable defect mapping in manufacturing lines for large-area, single-crystal silicon solar cells and a variety of polycrystalline solar cells. For the polycrystalline cells, this technique can be used to perform grain orientation mapping, following the standard texture etching done in production.

One of the most remarkable features of this new capability is the speed at which these high-resolution measurements can be accomplished. A complete 6-inch wafer can be mapped in less than one second. This allows the tool to be incorporated directly into a manufacturing line, monitoring the quality of the photovoltaic (PV) solar cells and allowing for real-time line corrections. This new capability will increase solar cell performance and yield, which will ultimately result in lower costs for the consumer. The characterization tool was designed for incorporation with the PV Reflectometer, an NREL innovation that won an R&D 100 Award in 1993. The PV Reflectometer measures the average reflectance of an entire wafer or cell as a function of wavelength, and the device is now commercially available from GT Solar.

Bob Bruggeworth, president and CEO of RF Micro Devices, shakes hands with Dan Arvizu, director of NREL, after signing a research agreement with NREL at the company's headquarters. RF Micro Devices was drawn to NREL by the technical promise of the IMM solar cell.

Reflective Surface Keeps NREL's Record-Breaking IMM Solar Cell Cool Under Concentrated Sunlight

Researchers at NREL's National Center for Photovoltaics continue to advance the technology of their IMM solar cell, the first to achieve a solar conversion efficiency of greater than 40%, and the winner of both an R&D 100 Award and an Editor's Choice award from R&D Magazine in 2008 (see pp. 8-9). The latest advance takes advantage of a unique characteristic of the cell to help it reject heat. Triple-junction solar cells like the IMM are literally grown layer by layer as crystals of semiconducting material. But unlike traditional triple-junction cells, the IMM is grown upside down, with the top layer deposited first and the bottom layer deposited last, on the top. To make use of the cell, it is flipped over, mounted to a "handle" material, such as a thin metal foil, and the substrate that the cell was grown on is removed. One advantage of this approach is that the expensive substrate can potentially be reused, achieving significant cost savings. That benefit has attracted the

commercial interest of RF Micro Devices, a leading semiconductor manufacturer (see insert on page 32).

Such triple-junction cells are typically used in concentrating photovoltaic devices, where lenses and mirrors concentrate the sun's energy, often to hundreds of times its normal strength. One problem facing such devices is the buildup of heat due to the concentrated depositing of lower-energy infrared radiation that does not contribute to the electrical current produced by the device. But because the IMM cell is built in reverse order, it's relatively simple to add an extra layer of reflective material, which becomes the bottom layer of the cell once the cell is inverted. This mirror-like surface reflects most of the unused infrared light back out of the cell, preventing it from being absorbed by the handle material. Preliminary work at NREL to add such a reflective surface has resulted in a cell that reflects as much as 80% of the unused infrared light. This innovation dramatically lowers the operating temperature of the cell when it is exposed to concentrated sunlight. Tests are under way to quantify the extension in the lifetime of the solar cell resulting from this lower operating temperature.

NREL Certified Measurement Techniques Being Transferred to Industry

NREL's National Center for Photovoltaics, the long recognized leader in photovoltaic characterization, has recently transferred some of its critical "know-how" to a commercial testing laboratory. Newport Corporation became ISO 17025 accredited as a photovoltaic calibration laboratory, thanks to significant technology transfer from NREL's photovoltaic performance characterization group. An accurate and reliable means of characterizing the performance of solar cells is an essential component of any research and development program. The transfer of these measurement capabilities into the marketplace is essential to continue the rapid growth rate of the photovoltaic manufacturing industry. This most recent transfer of technology follows similar transfers made by NREL to both Underwriters Laboratories Inc. and VLSI Standards, Inc.

Development of CIGS Barrier Coating Leads to Longer Usability

NREL scientists succeeded in reducing the degradation rate of the "window layer" of thin-film solar devices based on copper indium gallium diselenide (CIGS) by a factor of four to five.

This is an advantage in any number of mobile power applications, including those for the military.

Thin-film solar devices based on CIGS have a number of advantages over traditional silicon-based solar cells, including the ability to be deposited on flexible substrates, resulting in a lightweight solar module that can be rolled up and easily carried into the field. Unfortunately, flexible CIGS modules have an Achilles' heel—they're susceptible to failure under long-term exposure to heat and humidity. The problem is in the "window" layer, a top layer of transparent conductive material, typically zinc oxide or indium tin oxide, which serves to collect the current from the device and deliver the current to the module's electrical terminals.

NREL Scientist Miguel Contreras and his team believe they solved the problem using a sputter-deposited layer of protective transparent metal oxide (PTMO). While further testing is needed, the new PTMO layers could double the warranty period offered by CIGS manufacturers, perhaps extending the lifetime of the modules to up to 50 years.

PV Interconnection Report Lights the Way

Sometimes a breakthrough comes by breaking through attitudes. Such is the case of an NREL report, *Photovoltaic Systems Interconnected onto Secondary Network Distribution Systems—Success Stories*, published in April. The report, which gained widespread industry attention, makes the case that solar PV power systems can be interconnected to secondary network distribution systems without harming the integrity of the electricity delivery system.

Utilities use secondary network systems in many urban or other areas with concentrated loads, drawing on multiple power lines and transformers to provide greater reliability than with more conventional radial networks. To make such a complex system work, the transformers are equipped with network protectors to keep power from flowing backward in any of the power lines. But by feeding power into the grid, PV systems can trip the network protectors in such systems, so utilities are reluctant to allow their connection.

The new report examines six case studies of PV systems that have been successfully connected to such secondary network distribution systems. Part of the solution is keeping the PV systems small to avoid causing the current in the distribution system to reverse direction, but special relays and inverters can also help to protect the network systems. The report was co-authored by a team of engineers

The high concentration of solar-powered homes in this development in Rancho Cordova, California, is providing new information about how such distributed energy sources interact with the power grid.

in the Distributed Energy Systems Integration Group of NREL's Electricity, Resources, and Buildings Integration Center, along with private-sector engineers.

As NREL engineer and report co-author Mike Coddington notes, "We expect to see a significant increase in PV system deployment in dozens of downtown urban areas across the United States in the next few years." Indeed, the report authors note that a recommended practice for interconnection of such "distributed generation" systems to secondary power networks is being developed by the Institute of Electrical and Electronic Engineers. When published and implemented as best practices, these new standards will enable widespread adoption of PV systems for residential use.

Solar Community Provides a Real-World Test of Electrical Grid Impacts

There are many questions about how PV systems might impact the electric grid, but finding actual data about this impact is often elusive. NREL's Peter McNutt and his team in the Grid Integration Group have found an ideal real-world lab to analyze the distribution impacts of high amounts of grid-integrated renewable energy systems. They began setting up their investigation in March 2009, in a growing community of PV-equipped homes in Rancho Cordova, California.

Plans ultimately call for 600 of the 795 homes in the subdivision to have solar systems that will generate 1.2 megawatts of power. As of March, 115 new homes had been built—all with PV systems. Answers to questions such as "Will there be excessive service voltage due to reverse power flow from exporting PV systems?" or "Will there be too much reverse power flow to the substation?" are unfolding as NREL monitors.

Preliminary results show no adverse effects on the substation or grid. If this finding holds up, it could provide strong support for those seeking to greatly expand the amount of solar power and renewable energy providing power to the grid. As the subdivision grows, McNutt and his group will continue analyzing any utility voltage events to see if the growing PV capacity will disrupt the system. But for now, the outlook remains bright in Rancho Cordova.

OpenStudio Software Adds to Architects' Efficiency Arsenal

New architectural software developed by NREL lets architects easily integrate building energy performance into their designs. OpenStudio™ software seamlessly integrates building energy simulation during the early design phases, enabling architects to evaluate energy-saving strategies when design changes are least costly.

Principal developer Peter Ellis of NREL sought to leverage two well established programs to create a whole that is much greater than the sum of its parts. OpenStudio is a plug-in that brings together the state-of-the-art building energy simulation capabilities of EnergyPlus™ with the easy-to-use 3-D drawing interface of Google SketchUp™. The combined features of the two programs offer architects and engineers capabilities that no other software on the market can offer.

Conventional building energy simulations require painstaking data entry or rely on detailed computer-aided design programs. Both of these factors discourage energy simulations in the early design phases, when most material decisions are being made. However, the OpenStudio plug-in allows the user to easily develop the architectural model and the energy model simultaneously. As a result, the software encourages architects to integrate energy performance into their building designs, rather than implementing it as a less effective add on once the building design is set in stone. The resulting change in mindset is expected to yield building designs that incorporate much better energy performance features.

Gearbox Reliability Collaborative Probes Wind Turbine Failures

Last summer, NREL researchers began investigating the reliability of the most critical component of a wind turbine—the gearbox. Gearboxes are the most expensive component to repair or replace on a wind turbine.

Sandy Butterfield, NREL project lead for the DOE Wind Turbine Gearbox Reliability Collaborative (GRC), says that some turbines get as little as three years' usage from gearboxes instead of the expected 20-year lifespan. In an effort to overcome this shortfall and validate the design process, the multi-year GRC program will conduct field tests, dynamometer tests, and analyses on two identical 750-kilowatt gearboxes.

The team collected its first dataset in July from the dynamometer at NREL's National Wind Technology Center. NREL's advanced instrumentation will provide more accurate test results and detailed information about the gearbox workings. Comparing the dynamometer results from similar measurements made in the field will provide researchers with a deeper understanding of the factors that impact gearbox performance and operating lifetime.

Offshore Code Comparison Collaboration Reaches New Depths

Jason Jonkman, who leads NREL's Wind Technology Center Offshore Code Comparison Collaboration (OC3) research team, knows that precise modeling codes are essential for designing robust and reliable offshore turbines. Jonkman's work on such codes, which began in fall 2004 in conjunction with international participants from Denmark, Germany, Spain, and the United Kingdom, passed a crucial phase in 2009. In June, the team outlined phase three of their work, which looked at 5-megawatt turbines set in 45 meters of water. Previously, the researchers had refined codes and model assumptions for turbines mounted on single towers in shallow water, but the design of turbines and support structures in deep water, farther out from shore, presented increasingly complex issues.

Generating power from offshore wind turbines has been described as the "new frontier" for wind energy.

An NREL team of scientists and engineers is using a dynamometer to investigate the reliability of wind turbine gearboxes. Pictured, from left to right, are Jeroen van Dam, Vahan Gevorgian, Mark McDade, Troy Boro, Cary Hertert, Shuangwen Sheng, Hal Link, Sandy Butterfield, and Ed Overly.

But before a single foundation is installed on the seabed, offshore wind power developers will rely on comprehensive simulation codes that account not only for wind flow, aerodynamics, blade elasticity, and power system controls, but also for how wind turbine support structures respond dynamically to waves, sea currents, and storms.

To address these issues, the OC3 team carefully defined a detailed set of offshore turbine structures and associated seabed conditions, which were selected to test different features of the models. Results from several simulation models were compared side-by-side for three- and four-legged offshore turbine support structures. The comparisons yielded a more thorough understanding of the appropriate assumptions and applicable ranges for the various models. Most importantly, lessons learned from this exercise have been used to improve the simulation codes being employed by engineers from six institutions as they design the next generation of offshore wind turbine structures.

Jonkman's team is currently working on a final, fourth phase of OC3, focusing on a floating buoy that supports the same 5-megawatt wind turbine. This stage of the project is expected to stretch the modeling capabilities of existing codes, as nonlinear effects become even more important to the analysis, due to the motion of the floating structure. The work continues to attract additional participants, as the design codes will be an essential tool in the development of this promising technology.

Offshore wind power has great promise as a future energy source for the United States. To prepare for that day, NREL is verifying the computer modeling codes that are used to design the support structures for offshore wind turbines.

Ethanol Group Cites Key NREL Study for Proposed Hike in Gasoline Blend Levels

Findings of an NREL team showed that the immediate impacts of mid-level ethanol blends—blending 15% to 20% ethanol into gasoline—showed no evidence of harming vehicle performance. The NREL research is key to informing decisions made by the U.S. Environmental Protection Agency (EPA) under the federal Renewable Fuel Standard.

Currently, regular blends of gasoline are allowed to contain as much as 10% ethanol. Referred to as E10, this blend constitutes the primary form of ethanol fuel available in the United States. The Renewable Fuel Standard requires that an increasing amount of renewable fuel such as ethanol be sold in the United States each year, and that becomes a particular challenge when gasoline consumption drops. In fact, for 2009, the EPA required most refiners, importers, and blenders of gasoline to displace 10.21% of their gasoline with renewable fuels such as ethanol, up from only 7.76% in 2008, in part because of a drop in gasoline consumption. That requirement is already pushing up against the "blend wall," that is, the maximum amount of ethanol that can be sold in the form of E10 (as well as E85 for flex-fuel vehicles).

When an ethanol industry group, Growth Energy, asked the EPA for a waiver to raise the percentage of ethanol blended into gasoline from 10% to 15%, it cited NREL research led by Keith Knoll in the Center for Transportation Technologies and Systems. The research is ongoing, and Knoll's team continues to collect and evaluate data aimed at identifying whether any deleterious long-term effects exist.

Understanding Tar Formation During Biomass Gasification

NREL scientists conducted research that could help biomass gasifiers operate trouble-free—leading to improved production of biofuels at significantly reduced costs.

One way to convert biomass into fuels and chemicals is to subject it to high temperatures, converting it to a gas. This gasification process is normally clean and efficient, but it can be hampered by the formation of sticky tars that gum up the works. The reduction or elimination of such tars is essential for achieving the full potential of biomass gasification, as the United States strives to meet its Renewable Fuel Standard, which calls for replacing 36 billion gallons of gasoline with renewable fuels by 2022. To address the tar problem, NREL's Mark Nimlos and his team in the National Bioenergy Center took up the challenge of studying the kinetic pathways of tar formation during gasification.

In their laboratory, the team put bits of biomass in a laminar entrained flow reactor, which quickly heated the biomass to 850°C. Then the researchers rapidly quenched the chemical reactions at varying times, providing snapshots of the chemical reaction processes in the form of the gas and char reaction products produced in the reactor. The team then used molecular beam mass spectrometry and other techniques to analyze the gas and char, thereby gaining an understanding of the reaction's progress.

The group was able to correlate the formation of tar compounds with the exact temperatures at which bubbles in the plant cell walls were bursting. Future work is focusing on the chemical reactions of these gases with other chemical compounds evolved within the system at that temperature. The team aims to develop a computer simulation that can aid in understanding and controlling the system's continued chemical reaction trajectory.

NREL Offers a Better Way to Cool Power Electronics in Advanced Vehicles

NREL technology is resulting in potential cost savings of advanced vehicles by eliminating a cooling loop presently employed to support converters and power electronic components.

Keeping yourself cool can be a challenge when driving your car on a hot day, and that challenge applies even more so to the power electronics that keep your car running. Hybrid vehicles and the new generation of plug-in hybrids and electric vehicles rely on large power electronic components that generate a lot of heat. The new NREL technology is the rough equivalent of a splash of cold water.

A team led by NREL Engineer Ken Kelly has developed a seal that allows liquid cooling to be applied directly to the underside of the electronic circuit boards, which are protected by a bonded layer of copper. That approach eliminated the use of thermal grease, which restricted heat flow, in order to significantly enhance the direct heat transfer from the circuit board. The team then employed a series of nozzles to direct jets of liquid coolant to the bonded copper layer. To apply even cooling, the NREL team drew on test results from single-jet experiments and used computational fluid dynamics to design their patented jet-impingement device. The design improvements reduced thermal resistance by 35% and also achieved a more uniform temperature distribution across the electronic devices, without increasing the pressure drop required for coolant circulation.

The NREL team then worked with engineers from Semikron to apply and demonstrate a similar cooling system for an inverter, a device that converts direct current from a battery to the alternating current needed to power electric motors.

Ken Kelly holds a Semikron inverter that has channels built into it for liquid cooling of its power electronics.

New Software Model Analyzes Investments in Fuel Cell Systems

Researchers at NREL's Hydrogen Technologies and Systems Center have developed a cost analysis model to evaluate investments in fuel cell systems that produce a combination of heat, hydrogen, and power. The model will help decision makers identify the cost and environmental benefits of implementing such fuel cell systems at their facilities. Developed in close consultation with the fuel cell industry, the model includes key cost data for fuel cell systems throughout their life cycle, and it uses a life-cycle discounted cash flow as its economic analysis framework, producing a levelized cost of energy for the fuel cell system. The model is flexible and easy to use, allowing users to range from those with limited knowledge of fuel cells to researchers in advanced fuel cell technologies.

The model analyzes stationary high-temperature fuel cell systems powered by natural gas, including phosphoric acid fuel cells and molten carbonate fuel cells. The system's energy performance is evaluated by drawing on building energy load profiles and solar and wind energy resource profiles for cities in all eight of the U.S. climate zones. NREL chose to model a combined heat, hydrogen, and power production system because it has the potential for near-term use, as the multiple energy outputs decrease the investment risk. Hydrogen produced by such a system can be stored for later conversion into electricity or to fuel a vehicle, thereby increasing the cost-effectiveness of the system.

SCIENCE AND TECHNOLOGY

Awards

NREL's innovations during FY 2009 were recognized by more than a dozen major awards—achievements that underscore its status as the nation's premier laboratory for renewable energy and energy efficiency research and development.

"Revolutionary" Solar Photovoltaic Technologies Garner More Recognition

NREL started the fiscal year by piling extra winnings onto two major awards that were received the year before. After claiming R&D 100 Awards in 2008 for two solar cell technologies—the inverted metamorphic multijunction (IMM) solar cell and a process that uses ink-jet printing to manufacture thin-film solar modules—NREL also received two Editor's Choice Awards from the editors of R&D Magazine. The editors named the two technologies "the most revolutionary technologies of the year."

The ink-jet printing technology involves a quick, simple method of applying metal-organic inks onto a substrate, such as a piece of metal or glass. Through a proprietary processing system, the ink layers are then subjected to heat and pressure to bond them together, forming large-grain crystals of copper indium gallium selenide (CIGS), one of several materials commonly used in thin-film solar cells. In contrast, conventional manufacturing methods require hours at temperatures up to 700°C or higher, as well as vacuum processing, evaporation, and other capital-intensive steps.

"This fast and economical ink-jet process paves the way for the mass production of low-cost thin-film solar cells," says David Ginley, an NREL research fellow and the principal investigator on the project. He and his team shared the award with HelioVolt Corporation, NREL's corporate partner on the project.

"We are excited about the cost reduction enabled by the innovations developed with NREL, and we are planning the incorporation of a number of these innovations into our large-scale manufacturing facilities," says Louay Eldada, Chief Technology Officer of HelioVolt.

NREL's research in thin-film solar technology, including Ginley's work on CIGS cells, led Colorado Governor Bill Ritter to present the Governor's Award for Research Impact in Renewable Energy to NREL officials in February at the Governor's Mansion. The award is one of five inaugurated by CO-LABS, a nonprofit organization that educates the public about technology innovation at Colorado's 24 federal research labs.

"These awards are a testament to the fact that this laboratory is about connecting high-impact innovation to the marketplace," says NREL Director Dan Arvizu.

While much of the thin-film research in PV manufacturing is aimed at producing low-cost solar devices that typically convert less than 20% of the sunlight hitting them into

David Ginley and his research team at NREL worked with HelioVolt to devise a low-cost method of fabricating thin-film solar cells made of copper indium gallium diselenide, or CIGS. Pictured, from left to right, are Alex Miedaner, Calvin Curtis, David Ginley, Jennifer Nekuda, and Maikel van Hest.

Scientists Mark Wanlass (left) and Jeff Carapella (right) build an IMM solar cell in their NREL laboratory.

electricity, the IMM solar cell is at the other end of the spectrum of solar cell technologies, offering a higher-cost device that has a conversion efficiency of more than 40%. The IMM solar cell draws on two different technology innovations to solve a material challenge that has dogged the creators of high-efficiency solar cells for years. So-called multijunction cells consist of several stacked layers of solar cell material, with each layer tuned to capture a specific part of the solar spectrum. The layers are literally grown on top of one another as crystals of semiconducting material. However, the cells have always fallen short of their potential, cracking or forming defects that significantly lower their efficiency.

The IMM solar cell solves that problem in two ways. First, the cell is grown from the top layer down, thereby limiting the stresses imparted by the bottom layer to the upper layers during the fabrication process. Second, a transition layer is added before the bottom layer is deposited. This "metamorphic" layer gradually changes in chemical composition as it is deposited, shifting its lattice spacing to match up with the bottom-layer material. The result is a firmly bonded device that is relatively free of atomic-scale defects. The achievement broke a world record for solar conversion efficiency, converting more than 40% of the incoming sunlight into electricity.

Since 2005, NREL has worked with Emcore Corp. and the Air Force Research Laboratories Space Vehicles Directorate at Kirtland Air Force Base in Albuquerque, New Mexico, to develop a commercial version of the IMM cell under a Cooperative Research and Development Agreement (CRADA). The success of those commercialization efforts led the Federal Laboratory Consortium (FLC) for Technology Transfer to also name the IMM solar cell a winner of the 2009 Award for Excellence in Technology Transfer.

One of NREL's top solar researchers also won a prestigious award this year. Senior Research Fellow Art Nozik won the 2009 Intergovernmental Renewable Energy Organization (IREO) Award for Science and Technology. IREO is a new international organization, affiliated with the United Nations, which aims to implement pilot projects to educate and promote the use of renewable energy around the world.

The award recognizes energy innovators who are "leading the way of global development through renewable energy, with the strength to challenge conventional wisdom and encourage critical thinking," according to the IREO. Nozik, in particular, was recognized for "his decades of research in solar energy and efforts in promoting renewable energy in the United States."

Concentrated Solar Power Devices Earn Top Awards

FY 2009 will also be remembered as a banner year for NREL's concentrating solar power (CSP) program. Despite its modest size, this resurgent program captured a pair of coveted R&D 100 Awards.

The CSP program won one of its awards for a high-efficiency parabolic trough collector for utility-scale solar thermal power

The Ultra-Accelerated Weathering System concentrates ultraviolet light on test samples while rejecting the solar wavelengths that would cause the samples to overheat.

plants. Parabolic troughs are literally trough-shaped mirrors that concentrate the sun's heat onto a central tube, or "receiver," which carries a fluid that collects the heat. The hot fluid is then used to boil water to steam, driving a turbine to produce electricity. Most parabolic troughs are made with heavy, expensive glass mirrors.

Manufactured by SkyFuel, Inc., the new award-winning parabolic trough employs a weatherproof, high-reflectance polymer film developed in a partnership between ReflecTech, Inc. and NREL. The ReflecTech® Mirror Film material replaces the traditional glass-based reflectors, rendering the entire structure lighter, less expensive, more weather-resistant, shatterproof, and easier to maintain. This will help widen the use of CSP in utility markets by addressing the primary market barriers—high up-front capital costs and the durability and maintenance over the multi-year payback period required for profitable operation.

ReflecTech Mirror Film is the product of years of collaboration between independent researcher Randy Gee and NREL engineer Gary Jorgensen.

Over the course of a decade, Gee and Jorgensen worked at encapsulating a very thin layer of highly reflective silver within thin sheets of polymer material, receiving a patent for the material in 2007.

That collaboration also earned recognition from the Mid-Continent Region of the FLC, which lauded NREL and SkyFuel with an Award for Excellence in Technology Transfer in 2009.

The CSP program also won an R&D 100 Award for a spinoff technology. The Ultra-Accelerated Weathering System (UAWS) is a multifaceted, ultraviolet solar concentrator that speeds up the exposure of materials to sun and weather.

This unique and much-needed capability was named an R&D 100 Award winner because it allows researchers and engineers to see the degradation caused by long-term weathering without having to wait years or decades for results. Unquestionably, results from such accelerated weather exposure lifetime testing will greatly inform CSP technology commercialization decisions and lower risks for the investment community.

The UAWS is not an energy-producing technology, but it draws on the experience of the CSP program, using mirrors that are uniquely faceted to split sunlight's spectrum so that only the ultraviolet (UV) light hits the test surface. This UV light is up to 100 times more concentrated than natural sunlight—shattering the currently employed industry norm by a factor of 20. At the same time, the visible and near-infrared parts of the spectrum are eliminated, keeping the surface relatively cool and avoiding unrealistic results.

The UAWS is the culmination of more than a decade of collaboration between NREL, the Russian Institute of Laser Optical Technology, and Atlas Material Testing Technology, all of which shared the award. By weathering materials with this system, researchers and engineers can determine the risks associated with development of new products, which in turn helps manufacturers devise warranties for those products. The accelerated weathering market is estimated to be at least $125 million per year.

Solid-State Lithium Battery Wins a Third R&D 100 Award

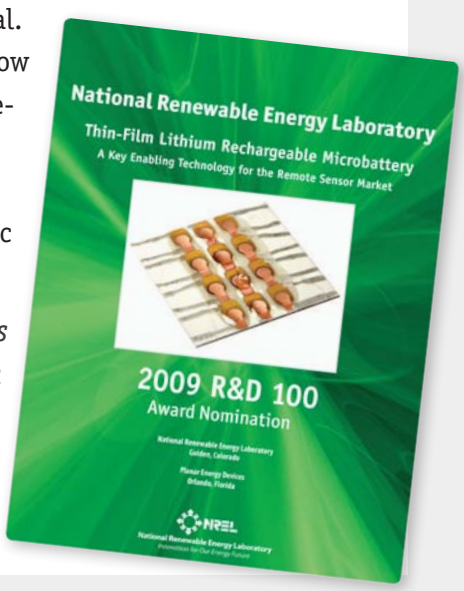
While solar technologies and researchers garnered the most awards in FY 2009, a small microbattery born from a window technology also produced an R&D 100 Award for NREL. Researchers in electrochromic windows—windows that darken when voltage is applied to them—realized that their expertise could help solve a problem plaguing solid-state lithium batteries.

The relatively new batteries typically have a delicate lithium layer as their top layer, or anode, requiring the battery to be encapsulated to protect it from damage and corrosion. The NREL team realized that they could chemically trap the lithium in a cathode, which could form the top layer of the device. When initially charged, the lithium migrates to the bottom of the battery and plates out, forming the lithium anode.

With the delicate anode at the bottom of the battery, typically sandwiched between a stainless steel substrate and the upper layers of the battery, this "buried anode" approach promises durable, long-lived lithium batteries. Planar Energy Devices licensed the technology from NREL and commercialized it as the PowerPlane UX Microbattery, a safe, rechargeable, deep-cycle microbattery.

Unlike traditional batteries, the PowerPlane® UX Microbattery has a long lifecycle even if it is frequently charged and fully discharged. That makes it ideal for powering remote sensors, which are a key technology for more efficient "smart" buildings, industries, and vehicles. In inaccessible parts of buildings and vehicles, the battery can be teamed with an "energy harvesting" device, which would draw on vibrations, temperature differences, or even radio waves to generate the power needed to recharge the battery.

Planar shares the R&D 100 Award with NREL, and that collaboration also won an award for excellence in technology transfer from the Mid-Continent Region of the FLC. Although the company is happy with the awards for the microbattery, Planar has its sights set on a much bigger goal. The company is now developing a large-format battery that could power tomorrow's electric vehicles.



Since its inception in 1977, NREL has won 45 R&D 100 Awards.

SCIENCE AND TECHNOLOGY

New Partnerships and Developments Speed the Transition to Clean Energy

Getting renewable energy and energy efficient technologies to market quickly is part of the solution to mitigating global warming, reducing pollution, boosting local economies, and reducing the nation's dependence on foreign oil. NREL uses partnerships—with academic and research institutions, and companies throughout the world—to hasten commercialization of these technologies. In FY 2009, NREL forged ties with a number of organizations and started participating in six new Energy Frontier Research Centers (EFRCs).

NREL Plays Key Role in Two Energy Frontier Research Centers, Assists in Five Others

In August 2009, U.S. Energy Secretary Steven Chu announced a major effort to accelerate the scientific breakthroughs needed to build a new 21st century energy economy. The DOE allocated $377 million in funding for 46 new EFRCs located at universities, national laboratories, nonprofit organizations, and private firms across the nation. The EFRCs look toward the future, addressing current fundamental scientific roadblocks to clean energy and energy security.

Among those 46 EFRCs is the Center for Inverse Design, located at NREL. This new EFRC will perform advanced scientific research on the materials needed for clean energy production. Alex Zunger, an NREL research fellow, is the director of the Center for Inverse Design, and researchers from Northwestern University, Oregon State University, and the SLAC National Accelerator Laboratory will partner with NREL. The center is expected to receive $4 million per year for five years.

"The center will bring together a multidisciplinary team of researchers to design new semiconductors in a unique approach that will dramatically increase the speed and scale of materials discovery," says NREL Director Dan Arvizu.

Zunger says the new center "will embark on daring research that uses quantum theory and high-performance computers to design new materials that have desired properties, and then use state-of-the-art synthesis to make them in the laboratory."

The term "inverse design" refers to the deliberate design of materials possessing customized properties, versus the traditional approach that uses accidental discovery. Zunger says it's like playing "Quantum Jeopardy": Given the answer (a material having certain unique and useful properties), researchers must find the question (what material is it?).

The approach may be key to the large-scale deployment of renewable energy technologies, particularly solar energy, because it could help find more common materials for use in solar cells. For instance, the largest solar module company in the United States, First Solar, relies on cadmium telluride to convert sunlight into electricity. But meeting the world's future energy needs with this technology is considered impossible, because there is not enough tellurium to create the volume of solar cells that will be needed.

We need to find a more common material that can perform the same function, and that's the type of problem that the Center for Inverse Design is meant to solve. The inverse design approach—choosing the function and then finding the material—could also lead to other scientific breakthroughs.

"This could usher in a new era of materials science—not only in renewable energy, but in other technology areas where specialized key materials are needed," says Zunger.

NREL also began partnering with the Los Alamos National Laboratory to share a five-year, $19 million grant from DOE for a joint EFRC called the Center for Advanced Solar Photophysics. The University of Colorado (CU) and Colorado School of Mines (CSM) will participate in the new EFRC as well, with the Colorado

Collaboratory providing matching funds of at least $300,000 over three years.

NREL helped create the Collaboratory in February 2007 in association with CU, CSM, and Colorado State University (CSU). The Collaboratory works with public, private, and nonprofit entities, helping to build a new "clean energy economy" in Colorado, in part by creating new research centers with tightly focused missions.

This new research focuses on nanotechnology to advance solar energy technologies. Nanotechnology involves working with materials at the scale of a billionth of a meter, or nanometer. For comparison, the diameter of a human hair is 10,000 nanometers.

Working at the nanoscale allows scientists to control matter and develop new materials and structures with novel and powerful properties. EFRC researchers will explore how nanoparticles interact with light and study nanometer-scale structures that manipulate how the sun's light is absorbed and how electrons move.

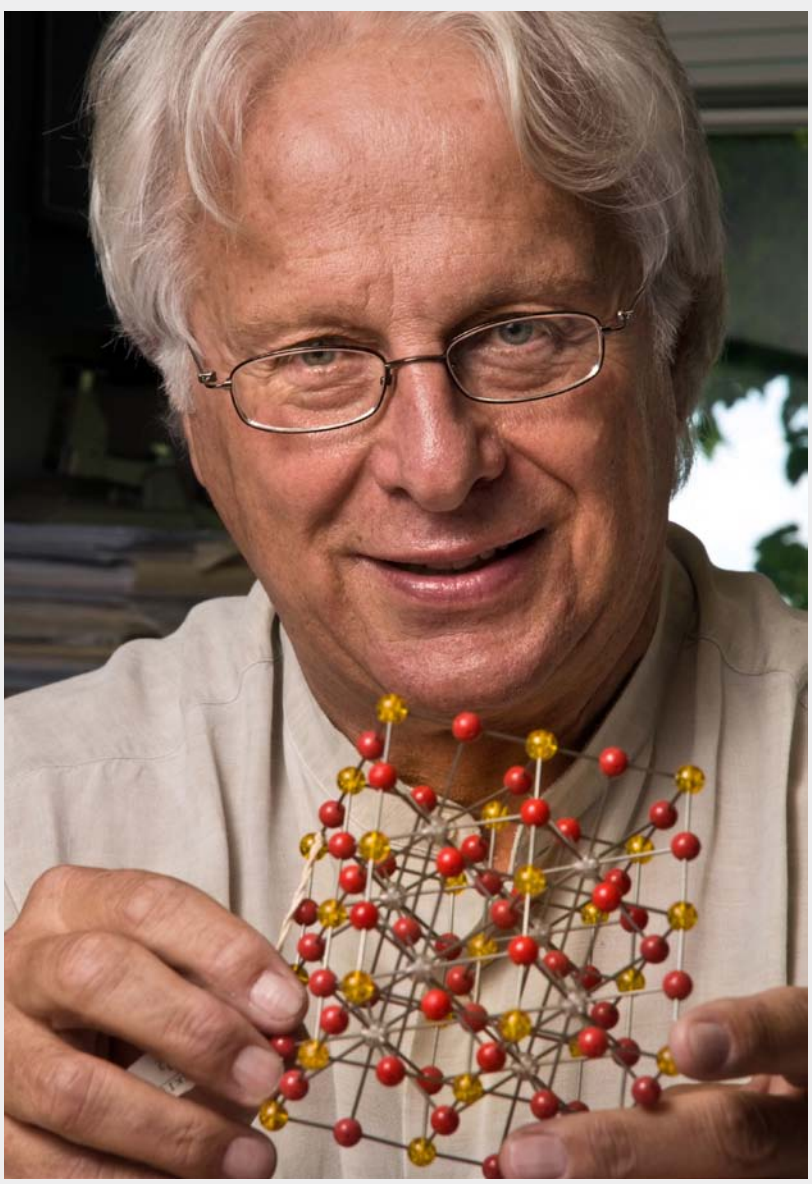
NREL is also participating in five other EFRCs:

- The Center for Molecularly Assembled Material Architectures for Solar Energy Production, Storage, and Carbon Capture, led by the University of California, Los Angeles
- The Center on Materials for Energy Efficiency Applications, led by the University of California, Santa Barbara
- The Center for Interface Science: Hybrid Solar-Electric Materials, led by the University of Arizona
- The Center for Direct Catalytic Conversion of Biomass to Biofuels, led by Purdue University, and
- The Center for Polymer-Based Materials for Harvesting Solar Energy, led by the University of Massachusetts.

New Center for Revolutionary Solar Photoconversion Launches a Dozen Projects

The newest research center within the Colorado Collaboratory is the Center for Revolutionary Solar Photoconversion (CRSP), with NREL's Arthur Nozik serving as the scientific director. Created in 2008, CRSP concentrates on ways to convert the sun's energy to clean, low-cost electricity and fuels. The center also supports education and research opportunities to develop the workforce to support the new energy economy.

There are 15 member companies that help fund CRSP's shared and sponsored research programs: Applied Materials, Inc.; Ascent Solar Technologies, Inc.; DuPont; Evident Technologies, Inc.; Konarka Technologies, Inc.; Lockheed Martin Corp.; Motech Industries Inc.; QuantumSphere, Inc.; Sharp Corporation; Solasta, Inc.; SunEdison, LLC; Toyota Motor Sales, U.S.A., Inc.; General Motors Corp.; QFlux Inc.; and G24 Innovations, Ltd.



Through the new Center for Inverse Design, NREL Research Fellow Alex Zunger will lead an effort to design new semiconductors that can meet the energy challenges of the future.

In October 2008, in its inaugural round of research and development funding, CRSP launched 12 solar research projects totaling more than $1.1 million. The projects will be funded for up to two years by contributions from CRSP's corporate members and matching funds from the State of Colorado. Of the dozen projects, six include NREL researchers.

"These projects represent the leading edge of research into both new ways to generate electricity and liquid and gaseous fuels directly from the sun, and improving our approaches toward these goals," says Nozik.

While the Collaboratory has yielded CRSP, CRSP has also resulted in a new partnership agreement. In July 2009, CRSP and the Renewable Energy Materials Research Science and Engineering Center (REMRSEC), which is located at CSM, announced their affiliation, which will add value to both centers and enhance their work on solar energy research. The REMRSEC was created in the fall of 2008 by the National Science Foundation (NSF), earning a distinction as the first NSF-funded center dedicated solely to renewable energy. CSM received $9.3 million to establish the center, which will investigate emerging renewable energy materials and technologies. CU and other organizations will participate in the research.

Dan Bilello and John Barnett are leading NREL's international efforts.

NREL Goes Global with New International Research Partnerships

Because energy production and use are critical to the global economy, NREL collaborates with research partners around the world. NREL's global leadership and partnerships were dramatically advanced during 2008, when NREL signed agreements with organizations in three countries: Brazil, China, and Germany. According to NREL Director Dan Arvizu, expanding the lab's international profile is vital if renewable energy technologies are to reach their commercial potential and help to slow the effects of carbon-based emissions on the planet's climate.

"We need to lead globally," says Arvizu. "I can't over-emphasize it."

That global leadership kicked off on November 11, 2008, when Arvizu signed a memorandum of understanding (MOU) with the Institute of Electrical Engineering of the Chinese Academy of Sciences to expand collaboration in PV research. The two institutions have agreed to jointly develop a PV component and battery-testing center, probably in Beijing, as well as extensive data sharing and scientist exchanges. NREL will also be supporting a new eco-city partnership between Denver and the city of Chongqing to test and demonstrate electric vehicle deployment.

A week later, NREL and Petróleo Brasileiro S.A. signed an MOU to accelerate the development and international commercialization of second-generation biofuels from non-edible plant material and other sources. The two-year agreement was signed at the International Biofuels Conference in Sao Paulo, Brazil.

Brazil is the world's largest producer of biofuels—largely sugar-cane-based ethanol. The collaboration will focus on improving analysis and quality control of cellulosic ethanol conversion, developing diesel and jet fuels using petroleum substitutes from biomass sources, improving analytical modeling to forecast biofuels' sustainability and environmental outcomes, and sharing data on the performance of intermediate fuel blends.

Five days later, NREL signed an agreement with the German Aerospace Center to collaborate on advancing concentrating solar power systems, solar resource assessment, and other energy analysis research. Despite its northern location, Germany leads the world in installed solar capacity.

NREL and Industry Work to Cut Building Energy Use by Half

NREL and DOE's Pacific Northwest National Laboratory (PNNL) are working together to reduce energy consumption in commercial buildings in the United States. The research project, called Commercial Building Partnerships, involves 23 companies. Officially kicked off in mid-2008, the project really got rolling in early 2009. The 23 companies include such businesses as ProLogis, Best Buy, John Deere, Kohl's, SUPERVALU, Target, Toyota, and Whole Foods. Major real estate management companies are also participating, including CB Richard Ellis, Forest City Enterprises, Opus, and Ryan Companies U.S., Inc.

The NREL and PNNL team will create, test, and validate design concepts that will move the industry toward net-zero-energy commercial buildings. Commercial Building Partnerships is part of DOE's Net-Zero Energy Commercial Building Initiative, which was mandated by the 2007 Energy Independence and Security Act. The initiative's goal is to develop market-ready, net-zero-energy commercial buildings by 2025. A net-zero-energy building produces as much energy as it uses over the course of a year.

Currently, retail and office buildings consume 18% of the nation's total energy and half the nation's overall building energy. The program partners will work in the near term to build new facilities that use 50% less energy and to retrofit older buildings to use 30% less energy. Daylighting, refrigeration, and LED parking lot lights are some of the energy design measures the teams are beginning to tackle. Greg Stark, who leads the NREL team on the project, estimates that the work will involve 14 design and construction projects, including a mix of building retrofits and new building construction.

According to NREL Engineer Paul Torcellini, the fiscal bottom line provides the business motivation for industry to participate, because energy efficiency is a good investment that pays for itself. Under the Commercial Building Partnerships project, NREL provides technical and research support to help these companies achieve energy efficiency and financial savings.

"When questions arise or trade-offs need to be evaluated," says Torcellini, "NREL performs the analysis to identify the approach that leads to optimized efficiency and maximum value for the company."

NREL involvement in the building industry is steadily growing in stature. In June 2009, NREL Research Supervisor Sheila Hayter was elected vice president of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), an international organization with about 50,000 members. ASHRAE helps to advance building technologies through research, standards writing, publishing, and continuing education to serve humanity and promote a sustainable world.

BUILDING THE *LABORATORY OF THE FUTURE*

A rapidly growing clean energy industry; a new U.S. president who sees clean energy as a source of new "green collar" jobs; an economic recovery act that directs billions of dollars toward renewable energy and energy efficiency; and a growing realization throughout the country that energy efficiency and renewable energy play key roles in addressing global climate change, international energy security, and U.S. energy independence: these are the stars that aligned in 2009 to help spur rapid growth at NREL. The national laboratory is now well on its way to achieving its vision of the laboratory of the future.

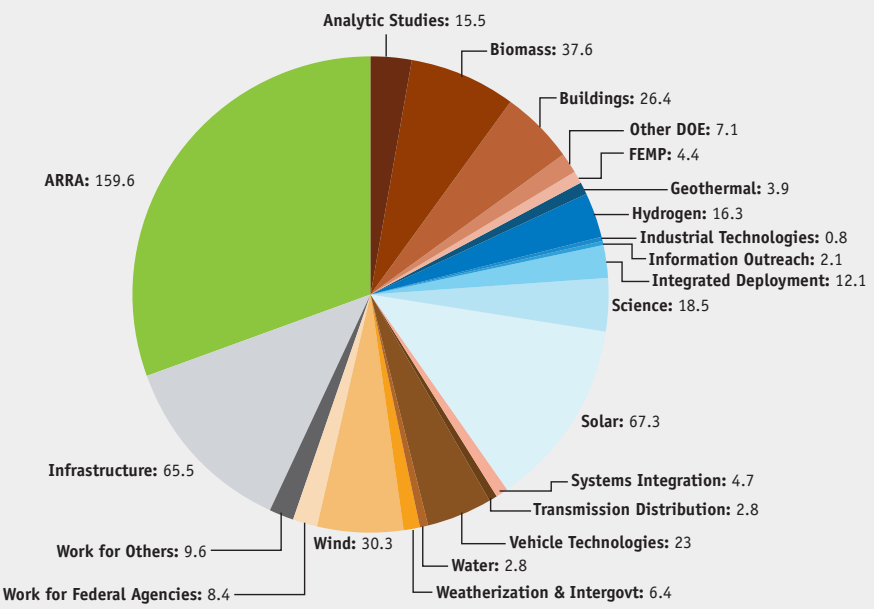
BUILDING THE *LABORATORY OF THE FUTURE*

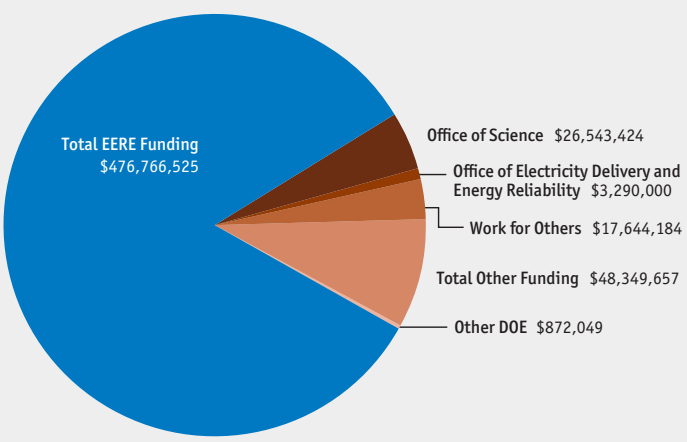
NREL was already in the middle of a major expansion when President Barack Obama signed the American Recovery and Reinvestment Act of 2009 on February 17. The laboratory had recently completed work on the Science and Technology Facility (S&TF) and had started construction of the Research Support Facility (RSF), the first office building that NREL has built on its permanent site. So NREL's construction projects were more than just "shovel-ready"; the laboratory literally had boots on the ground. The waffle-soled boots of construction workers, that is.

In late April, DOE awarded more than $110 million in Recovery Act funds to NREL, providing the largest single injection of capital funding in the laboratory's history. The funds included $68 million for the RSF; $13.5 million for upgrades to the Integrated Biorefinery Research Facility, a project that is slated for construction in 2010; $10 million for the National Wind Technology Center; and $19.2 million to support the use of clean energy technologies to power NREL.

Recovery Act funding provided through DOE programs added another $50 million to NREL's budget, bringing total Recovery Act funds to nearly $160 million. The massive injection of new funds significantly skewed NREL's budget for FY 2009 to the positive, increasing the overall budget by more than a third.

But NREL wasn't caught unprepared. In fact, the laboratory's management has spent years examining how NREL should grow to meet the changing needs of both the nation as a whole and the burgeoning clean energy industry in particular. All that planning is now being realized as NREL moves swiftly toward building the laboratory of the future.





Nearly $160 million in funding from the American Recovery and Reinvestment Act (ARRA) boosted NREL's budget for FY 2009 by nearly 44%, bringing the total funding to $525.1 million for the fiscal year. More than 90% of NREL's funding came from the DOE Office of Energy Efficiency and Renewable Energy (EERE).

"I think a lot of the reason that we've done so well in the last couple years is because we were prepared for this level of success," says NREL Director Dan Arvizu. "We've created an outstanding laboratory. And it is great for what we've had to do, but it's not sufficient for what we need to do."

The Research Support Facilities: An Office Space That Doubles as a Living Laboratory

The most visible sign of NREL's expansion is the heavy construction underway on what may at first seem the most prosaic of needs: a new office building, the RSF. But large projects rarely take a standard approach at NREL, and the RSF is no exception. In addition to being a showcase of clean energy technologies, the RSF will also be a living laboratory for researchers to investigate the best ways to operate office spaces, achieving comfort and productivity while minimizing energy use.

The office building is itself a milestone for NREL. When the laboratory was first formed back in 1977, the State of Colorado gave the federal government a tract of land near Golden that includes a long swatch of gently sloping land running from west to east along the foot of a mesa, as well as the steep lands leading up to the mesa top, of which NREL also owns a portion (see illustration, pp. 20-21).

Development of that land has proceeded slowly in the past, starting with the dedication in 1984 of the Field Test Laboratory Building on the lower land tract and the construction of solar measurement facilities and a solar furnace on the mesa top. NREL also established the National Wind Technology Center on a separate campus just south of Boulder, about 15 miles north of the main site. NREL was initially called the Solar Energy Research Institute, and as it gradually developed, nearly all the offices and many of the laboratories were located in leased office space. That was still the case in 1991, when the institute was designated as a national laboratory and changed its name to NREL.

Developing the "permanent site," has always been a long-term goal at NREL, but that goal has often appeared out of reach. While many other national laboratories were located on former military bases, providing ready-made infrastructure to build upon, NREL has had to start from scratch. Funding for laboratory space is easier to obtain than funding for office space, so NREL's history is one of building new laboratories. During a growth spurt in the 1990s, DOE funding allowed NREL to build the Solar Energy Research Facility (SERF), the Alternative Fuel Users Facility (AFUF), and the Thermal Test Facility.

Thanks to support from DOE, NREL started its current campus

Construction of NREL's Research Support Facilities proceeded apace in FY 2009.

growth in 2005, as it began construction of the Science and Technology Facility (S&TF). The 71,000-square-foot facility was completed in 2006, providing new laboratories for research in solar energy, hydrogen, and other clean energy technologies. Following NREL's ethic of combining energy efficiency, renewable energy, and other green building techniques, the S&TF was the first federal building to earn a LEED Platinum certification from the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program.

The building includes efficient windows and air handling equipment, and takes advantage of natural daylighting, evaporative cooling, and heat recovery from exhaust air. The S&TF also includes 11% recycled materials, while 27% of the building materials were manufactured nearby. In early 2008, the S&TF was named Laboratory of the Year for 2007 by R&D Magazine.

While construction of the S&TF was underway, NREL turned its attention to its office space needs. With $10 million in initial DOE funding, NREL started design and construction of the RSF. The intent was to build just the first two wings of the building, a project that would cost about $80 million and require five years of design and construction. That changed in April when DOE's award of $68 million in Recovery Act funds for the RSF gave a green light to the third wing of the building.

The first two wings of the building, now under construction, will feature 218,000 square feet of office space, enough to move 800 NREL and DOE administrative staff out of leased office space. The facility will include a library, a fitness center, and a commons area. The third wing will add another 150,000 square feet of office space, enough for 500 to 600 employees.

Capitalizing on the green building success of the S&TF, the RSF is designed to achieve LEED Platinum certification. An important aspect of achieving that goal is to maximize the use of daylighting by allowing light to penetrate deep into the building. That, in turn, requires a new approach to the traditionally walled-off office spaces.

The RSF will realize NREL's vision for the office of the future, which includes cubicle walls that are only 42 inches high—easy to see over, even while sitting—and bookshelves that are limited to 54 inches in height. Managers will have 6-foot privacy walls, but with the 13-foot ceilings, their offices will still be somewhat open. The low walls and open design allow not only for daylighting, but also for efficient air circulation throughout the building.

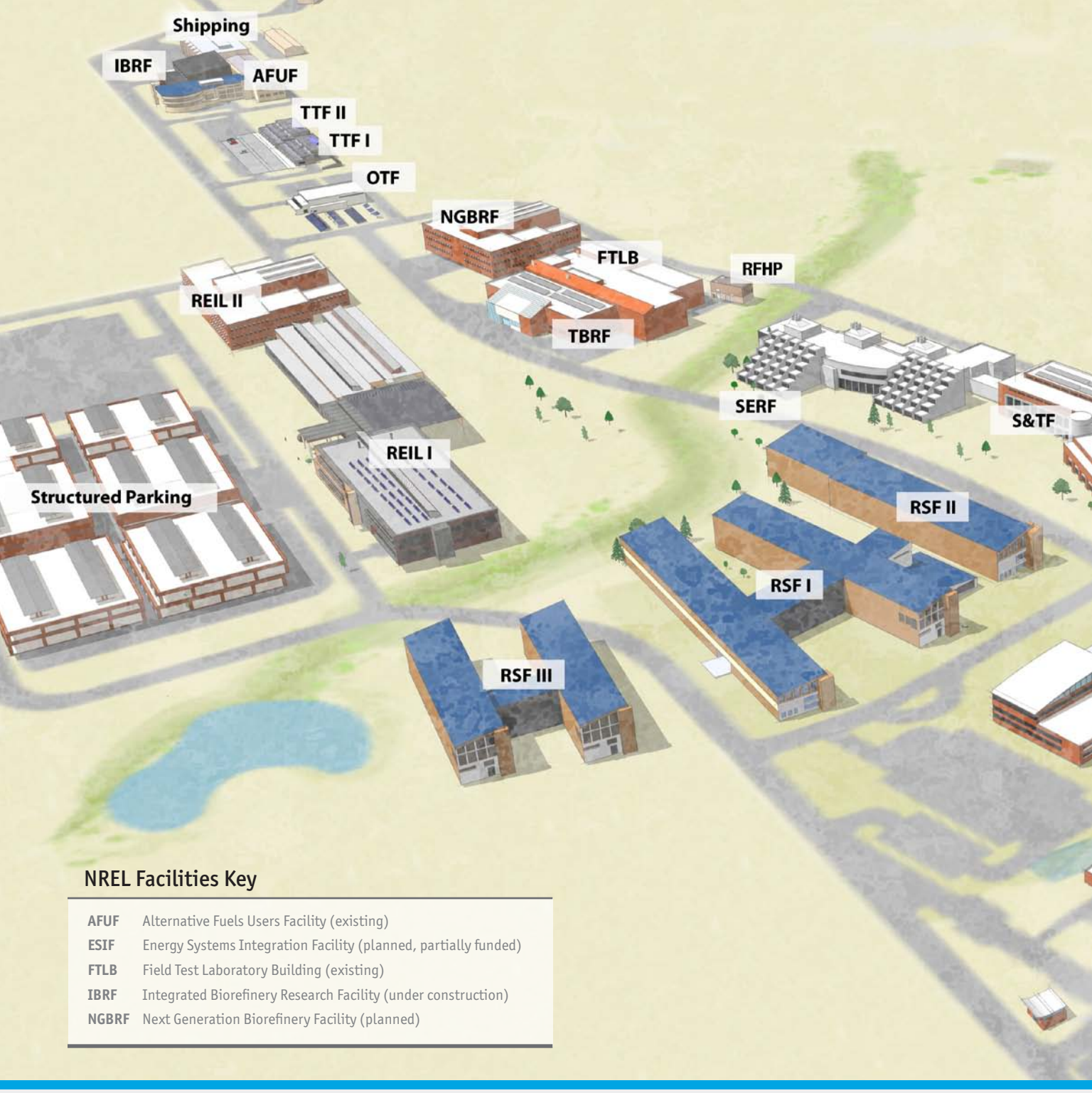
Because this office setup is different than the traditional modern office combination of walled offices and cubicles, the RSF will in some ways be a living laboratory for the office of the future. As the RSF is being built, NREL is testing the new office configuration in a separate building to try to understand the social dynamics of the new offices and to address any issues. For instance, one obvious requirement was for noise-cancellation technology to keep the office from sounding like the NASDAQ trading floor. The NREL staff that are using the new office design have generally reported the experience as positive, giving credence to the feasibility of the design.

The RSF will draw its ventilation air from a labyrinth of cement tunnels in its basement, using the tunnels as a thermal mass to absorb heat from hot, incoming air during the summer, and to help warm up cold incoming air during the winter. As another measure to help heat the winter air, a south-facing wall of the RSF will feature a transpired solar collector, which consists primarily of a large black metal sheet with thousands of holes in it, mounted on the exterior of the building. Ventilation air will be sucked through the holes in the metal sheet, or "transpired," passing through the warm space behind the metal sheet before entering the building. The combination of the solar collector and the labyrinth's thermal mass will heat the incoming winter air by as much as 10°F, providing a significant energy savings for the building.

The RSF will also feature a roof-mounted solar power system and natural ventilation to minimize its energy use. It will house a new data center, which can typically result in large energy consumption, but this data center will be a next-generation, energy-efficient design that will minimize its energy impact on the building as a whole. Over the course of a year, the RSF is expected to use as little as half the energy that a typical office building uses. Construction of the first two wings of the RSF will be completed in 2010; the third wing is expected to be completed in 2011.

Next Up: New Research Buildings for Biofuels and Grid-Connected Renewable Energy Systems

Construction has also started on the Integrated Biorefinery Research Facility (IBRF), which is being built adjacent to the existing AFUF.



NREL Facilities Key

AFUF	Alternative Fuels Users Facility (existing)
ESIF	Energy Systems Integration Facility (planned, partially funded)
FTLB	Field Test Laboratory Building (existing)
IBRF	Integrated Biorefinery Research Facility (under construction)
NGBRF	Next Generation Biorefinery Facility (planned)

The IBRF will allow NREL researchers to work simultaneously on multiple research projects, allowing for cooperative research with multiple partners from academia and industry. Like the RSF, the IBRF was originally planned to be built in two phases, but that changed with the injection of an extra $13.5 million in Recovery Act funding. With the extra funding, it's full speed ahead to achieve the complete vision for the IBRF.

The IBRF more than doubles the size of the AFUF, adding 27,000 square feet of high-bay area for process demonstration facilities, in addition to 3,800 square feet of new laboratories and nearly 12,000 square feet of office space. Construction of the first phase of the IBRF is scheduled for completion in 2010; the second phase is expected to be completed in 2011.

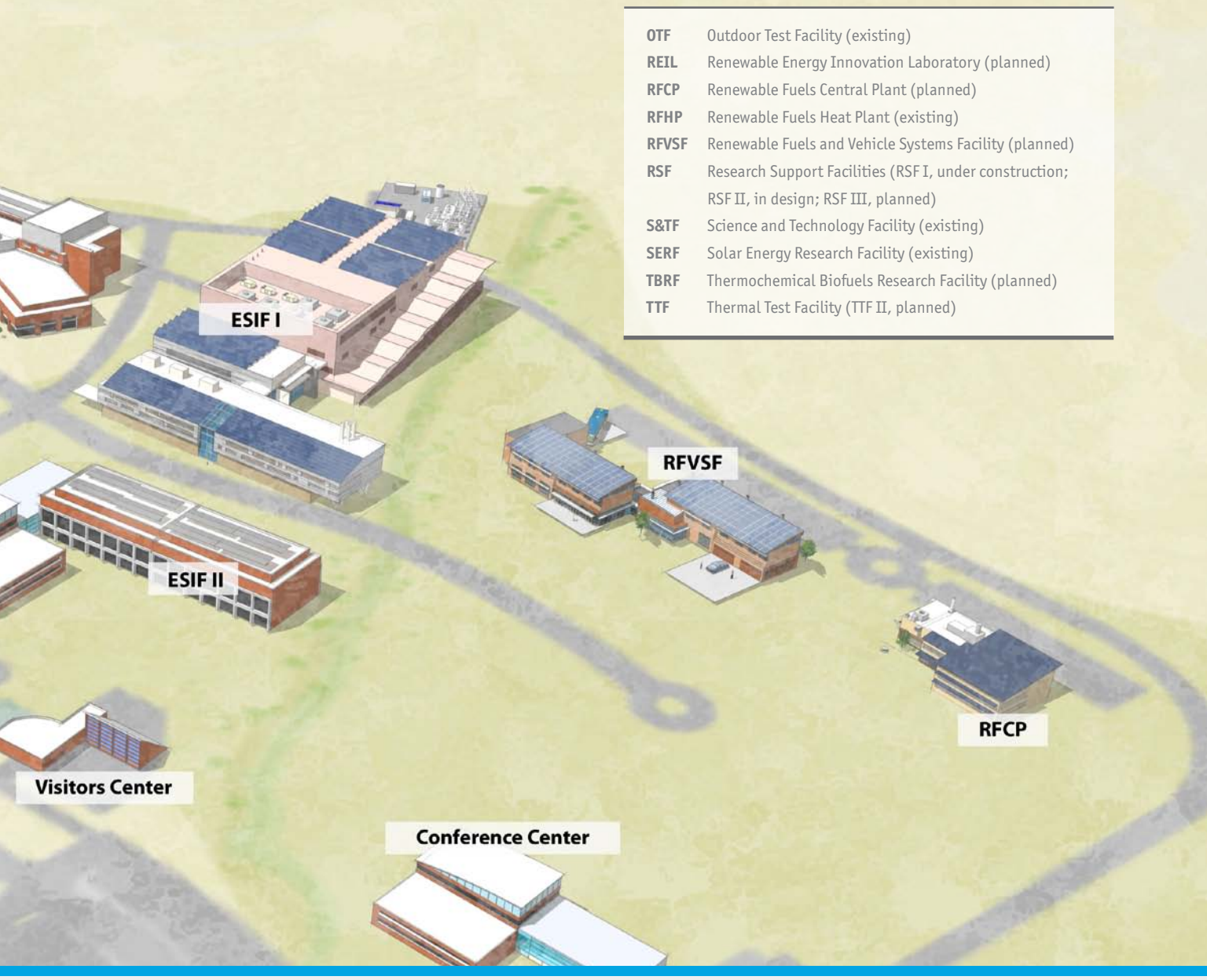
The IBRF will be followed by the Energy Systems Integration Facility (ESIF), which will be located southeast of the S&TF.

The 130,000-square-foot ESIF will house a variety of research activities that aim to overcome the technical barriers for connecting large amounts of renewable power to the electrical grid. As planned, the ESIF will be a multi-story building that will provide laboratory and office space for approximately 200-250 NREL researchers and support staff. Employees could possibly occupy the ESIF as early as 2012.

The ESIF will also provide a significant boost for NREL's computation science capabilities

NREL Proposed Full Buildout at 2021

Building the *Laboratory of the Future*



with the installation of NREL's first supercomputer. Supercomputers are measured in flops, or floating point operations per second, and NREL plans to install a 200 teraflop computer in the ESIF. That's a computer that can perform 2×10^{14} floating point operations per second. For comparison, a Pentium 4 processor operating at 3 gigahertz can achieve 12 gigaflops, which means the NREL supercomputer will be nearly 17,000 times faster.

The supercomputer is also scheduled for 2012, but NREL can't wait: until then the lab has signed an agreement with DOE's Sandia National Laboratories for an equivalent level of computing power. NREL relies on computers to perform such complex tasks as numerical simulations, which enable researchers to study complex systems and natural phenomena that would be too expensive or dangerous to study by direct experiments. In some cases, computation science can provide visualizations of phenomena that can't be studied directly, such as the interactions of enzymes with complex organic molecules.

"For NREL, this is just an exciting time, where we happen to be at the right place at the right time," says Drew Detamore, NREL's director of infrastructure and campus development. "We're in the spotlight; now we have to perform and build the laboratory of the future so that we have the kinds of facilities that will attract and retain the best talent, allowing NREL to fulfill its mission."

New Wind Turbines Go Up at the National Wind Technology Center

While most research branches of NREL prefer to build their equipment in new laboratory facilities, there is an NREL campus where much of the new equipment is built outside: the National Wind Technology Center (NWTC). Located north of the main campus near Boulder, the NWTC features a wide variety of wind turbines that are undergoing testing, including everything from small backyard wind turbines to large utility-scale machines. That variety became even greater in 2009, when NREL installed the two newest and largest additions to its collection of turbines.

The first addition, installed in August, is a 1.5-megawatt General Electric (GE) wind turbine that DOE purchased for the NWTC. Considered a main workhorse of the U.S. wind industry, the GE turbine accounts for about half of the U.S. wind market, with 10,000 of the turbines installed at wind power facilities throughout the United States. The turbine is mounted on a tower that stands 80 meters tall, or about 262.5 feet. The three turbine blades are each 38.5 meters long, or 126.3 feet.

NREL will study the turbine's performance in the field and will look for ways to advance its design. Among the questions researchers will address are the microclimate in which the turbine operates, the aerodynamics of the turbine design, and the effects of turbulence on its load and performance—as well as how all these factors may combine in potentially unforeseen ways. The NWTC was built at the base of the Rocky Mountains to take advantage of particularly gusty, turbulent winds, which challenge turbines under conditions not typically seen at commercial locations. NWTC researchers will also monitor the condition of the turbine gearbox as it is exposed to the harsh conditions.

"If we could improve performance, thousands of turbines could remain in operation for years beyond the industry's original expectations," says NREL Project Leader Jim Green.

The second addition, installed in September, is a 2.3-megawatt Siemens wind turbine. The turbine was provided by Siemens under a Cooperative Research and Development Agreement, or CRADA, which is expected to continue through 2014. The Siemens turbine is mounted on the same size tower as the GE turbine, but it will feature blades that are 50.5 meters long, or about 165.7 feet. That's more than 30% longer than the GE blades, giving the turbine rotor (the blades and the hub) a swept area that is 70% larger than the GE turbine. That greater swept area captures more energy, allowing the Siemens rotor to power its 2.3-megawatt turbine.

The Siemens turbine is among the largest turbines installed on land. NREL and Siemens will work together to gain a better understanding of the aerodynamics of such large wind turbines, including structural and performance testing, and monitoring it for power quality, vibrations, and acoustic effects.

NREL researchers are also interested in what happens beneath the ground that supports such large wind turbines, which can weigh

The large scale of the new NREL wind turbines is demonstrated by this worker, who is helping to guide two parts of the tower together as the top part is lowered by a crane.

400-800 tons. NREL and Renewable Energy Systems (RES) Americas, Inc. have entered into a CRADA to study the design and performance of the wind turbine foundations. RES Americas needed 80 trucks to deliver the concrete needed for the two new turbines at the NWTC. Under the CRADA, researchers will study the structural loads on the foundations of the new wind turbines and will also perform side-by-side comparisons of wind speed measurement systems.

NREL and RES Americas will also measure the thermal performance of the power cables, which pass under the turbines and deliver power to the electrical grid through an underground system. Part of the $10 million in Recovery Act funding for the NWTC will help pay for improvements to the NWTC's electrical distribution system, so that power produced by the two new turbines can be used either to power the facility or can be fed back into the power grid.

Building New Capabilities Behind the Scenes

While new buildings and wind turbines are the most visible additions to NREL, new research and testing capabilities are also being added within the lab's existing buildings. For example, of the $10 million in Recovery Act funds going to the NWTC, the lion's share is for doubling the capacity of an existing dynamometer to 5 megawatts, allowing it to test the great majority of wind turbines in use today. Like the dynamometers used for emissions tests on cars, which put each vehicle through a variety of performance tests, the wind turbine dynamometers subject turbines to variable speeds and torques, compressing 30 years of turbine use into a few months of testing.

This 1.5-megawatt General Electric wind turbine, purchased for NREL by DOE, was one of two large wind turbines installed at NREL in FY 2009.

While the NWTC is beefing up its wind turbine diagnostics, NREL's Hydrogen Technologies & System Center is developing new diagnostic tools for the mass-production of fuel cell components. Fuel cells are like batteries, except that a supply of fuel continually maintains a charge across the device. In the case of hydrogen-powered fuel cells, the device relies on a membrane that only allows the hydrogen ion to pass. Because a hydrogen ion is the same as a proton, these membranes are called proton exchange membranes (PEM), and the overall device is known as a PEM fuel cell.

Near the start of FY 2009, NREL launched a new fuel cell testing laboratory in the SERF, loaded with electrochemical test equipment to judge the performance of PEM

fuel cells. According to Principal Researcher Mike Ulsh, the primary function of the laboratory will be to study fuel cells with known manufacturing defects, in order to determine what magnitude of defects will impact the performance of the fuel cell. That information will allow NREL to design diagnostic tools that can catch troublesome defects, drawing on a wide range of diagnostic technologies.

The next step will be to build a small-scale manufacturing line for producing PEM fuel cell components. The manufacturing line will be used to verify the performance of the new diagnostic tools. NREL ordered the manufacturing line in 2009 and expects to install it in 2010.

NREL is also gearing up its testing of the heat generated by battery packs in vehicles. Battery packs store electrical energy for hybrids, plug-in hybrids, and all-electric vehicles, and as the latter two applications are becoming commercially available, larger battery packs are needed. For many years now, NREL has been testing the heat generated by hybrid battery packs with the use of a calorimeter, a device that encloses the battery pack and precisely measures the heat emitted from it. Unfortunately, the NREL calorimeter was not large enough for the bigger battery packs that will power the coming round of plug-in hybrids.

In preparing to order a larger calorimeter that would handle larger battery packs, NREL sought but found no company able to fill the order. Instead, NREL researchers built it themselves. The new calorimeter can handle battery packs as large as 100 inches deep and thick and 150 inches wide. The calorimeter has a measurement error of less than 1.5% for low-energy pulses, making it the most accurate calorimeter of its size in the world.

Powering NREL with Renewable Energy

With its new buildings designed to the highest LEED standards for green buildings, NREL has demonstrated that it is able to put its energy efficiency strategies into play in real-world settings, including laboratory settings. But part of building the laboratory of the future is to also draw on as much renewable energy as is feasible to power the laboratory.

For years, NREL has drawn on solar power installations throughout its campus, including a 118-kilowatt PV system installed on the SERF and smaller systems at other locations, including one at the entrance to the NWTC.

The NWTC site entrance building also draws on a 1-kilowatt wind turbine. NREL has done its best to make use of the electricity generated at its test wind turbines, and with the Recovery Act funds, it will be able to make the best use of the power generated by its new multi-megawatt wind turbines.

But in FY 2009, the lab made a major shift toward the use of renewable energy with two new facilities: the Renewable Fuel Heating Plant (RFHP) and a large solar power system. The RFHP uses a wood-fired combustion boiler to provide steam to the SERF, drawing on forest thinnings for fuel. Funded under an Energy Savings Performance Contract rather than with federal funding, the facility was privately financed for $3.557 million, which RFHP will pay back over the next 24 years through the energy savings that it achieves. The RFHP is expected to offset 75%-80% of the natural gas currently used on the NREL campus.

Meanwhile, NREL arranged for a 720-kilowatt solar photovoltaic system to be built on land the lab owns on top of the mesa. The Mesa Top Photovoltaic Array was financed and built by SunEdison, which owns, operates, and maintains the system. *(continued on page 26)*

The Renewable Fuel Heating Plant will offset up to 80% of NREL's natural gas usage.

Keeping it Safe

NREL reached unprecedented levels of construction in 2009, starting work on the RSF and IBRF while adding new multi-megawatt wind turbines, a wood-fired heating plant, and a large-scale solar power system. Yet despite the frenzied pace of construction, the lab successfully kept its focus on safety, avoiding any major injuries at the construction sites.

In fact, the laboratory had only one recordable injury at its construction sites in 2009—a broken thumb—and only a few cases where first aid was needed. Nobody missed work because of injuries at the NREL construction sites.

"Our safety record is in the top five percentile of how things can go," says Drew Detamore, NREL's director of infrastructure and campus development. "It's way at the top end of safety performance. There's a whole bunch of man-hours out there, and no significant injuries."

Of course, a lack of accidents doesn't happen by accident: it's the intentional result of careful planning, extensive training, and the integration of safety practices into every aspect of the lab's operations. Safety is emphasized with employees and contractors from the first day they step on campus.

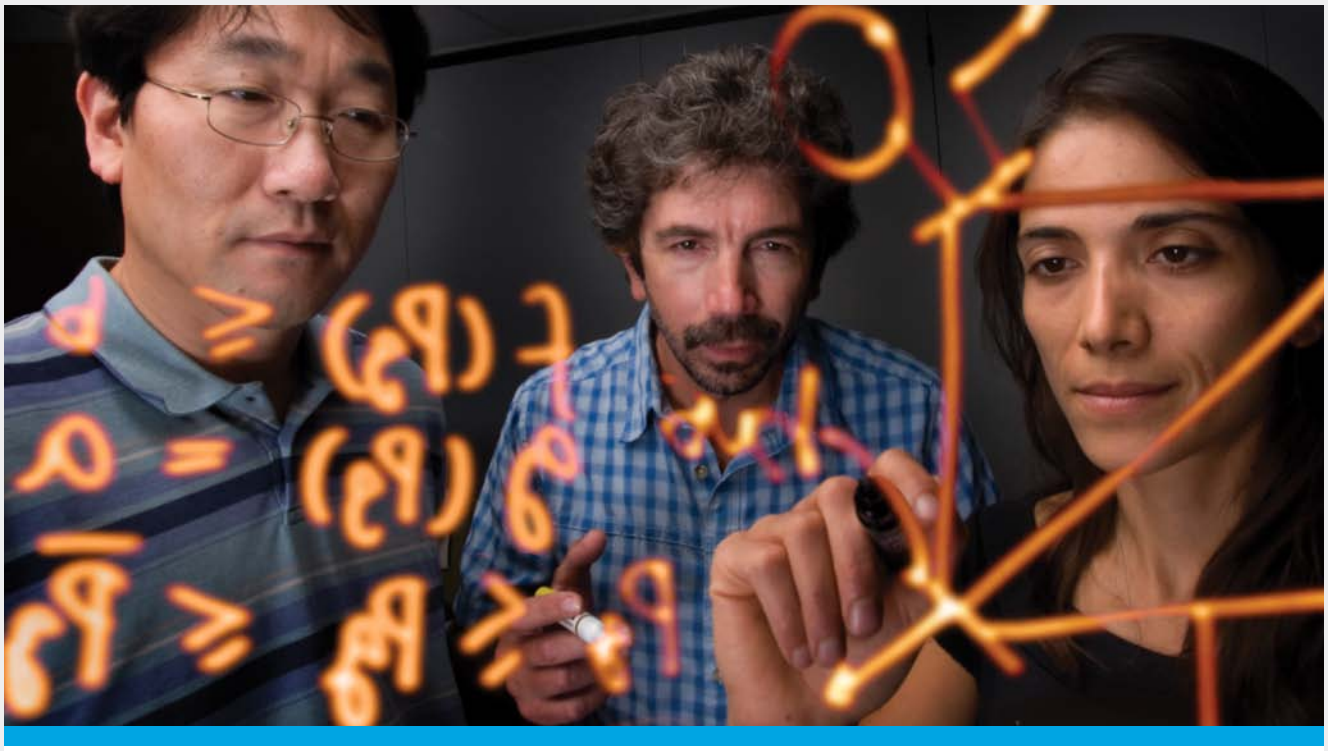
"It's due to the fact that there's a lot of safety participation by DOE, NREL, the design/build contractor, and all their staffs," says Detamore. "Everyone's engaged, and safety becomes part of the culture."

NREL will pay for the system by buying the solar power from SunEdison at competitive rates. The new array will provide 7.2% of the electricity used by NREL over the course of a year.

Solar power systems are going up all over the NREL campus. A 118-kilowatt system was added to the roof of the S&TF, and efforts are underway to build a 1.16-megawatt system at the NWTC, plus a 382-kilowatt system adjacent to the FTLB. And yet another 786-kilowatt system is coming soon, as the RSF will feature a solar power system on its rooftop.

NREL also received a boost from the Recovery Act for its efforts to power the lab with clean energy. An additional $19.2 million will support more onsite solar arrays and the potential addition of other energy sources, such as geothermal heat pumps and fuel cells. The new solar arrays are currently slated for the rooftops of the IBRF and the third wing of the RSF, as well as for covered parking for the RSF.

NREL's new Mesa Top Photovoltaic Array will provide more than 7% of NREL's annual electricity needs.



NREL is Hiring!

For most of 2009, the NREL home page had a feature on it that distinguished it from most other organizations in the United States: a gold star announcing that NREL is hiring. The gold star is now gone, but the laboratory remains in a hiring mode as it staffs up to meet our nation's rapidly growing and changing needs for clean energy.

NREL hired more than 440 new staff in 2009, bringing total employment at the lab to more than 1,800 as of the end of the fiscal year.

"We're approaching the point where we will have grown 100% over the last three and a half years," says NREL Chief Operating Officer Bill Glover. "One out of every two people that you meet as you walk around our campus wasn't here three years ago."

Nearly half of the new hires are supporting NREL's science and technology efforts, while the rest of the new staff are supporting outreach, planning, and analysis; laboratory operations; and commercialization and deployment—one area that has grown rapidly.

"We spent a large part of this year building our new directorate," says Casey Porto, NREL's senior vice president for commercialization and deployment. "We've grown 100% in the last year."

NREL is also gearing up to provide analyses of new policies and trends in clean energy, and to provide technical analyses of both the progress of clean energy and the roadblocks that are impeding its growth. That growth is expected to continue in the coming fiscal year.

NREL is also working to attract the best new engineering graduates to the laboratory. Gregg Beckham, an engineer in the National Bioenergy Center at NREL, is leading an effort to bring graduate-level chemical engineering students from the Massachusetts Institute of Technology (MIT) to NREL for two months of intensive research. During their stay, the students team up to tackle two consecutive research projects, each lasting four weeks.

The learning experience is being carried out under MIT's David H. Koch School of Chemical Engineering Practice, commonly referred to as the MIT Practice School. The Practice School allows students to apply their chemical engineering knowledge to assigned projects in an industrial setting. In 2009, NREL hosted eight graduate students, who split up into three teams to study a variety of processes relating to the conversion of biomass into second-generation biofuels.

"The projects may be short, but the students perform in-depth, rigorous work very quickly," says Beckham.

COMMERCIALIZATION & DEPLOYMENT

NREL's commercialization and deployment activities focus on accelerating the commercial application of new technologies and removing barriers to the market adoption of existing clean energy solutions. Through these efforts, NREL demonstrates the promise and marketability of emerging technologies and facilitates the use of existing technologies in the real world.

COMMERCIALIZATION & DEPLOYMENT

Commercialization

An entrepreneurial culture is resonating throughout NREL. It's entrenched in the lab's efforts to move technologies through the innovation pipeline and into the marketplace.

To foster this culture, NREL has established the Clean Energy Entrepreneur Center (CEEC), a new program for accelerating innovation, entrepreneurship, and commercialization both inside and outside NREL through research, education, and community development. As part of its educational efforts in FY 2009, the CEEC offered a short course in commercialization for NREL staff. As NREL builds its entrepreneurial culture, it has also launched new projects and a new advisory board to make intellectual property (IP) more accessible and to help clean energy companies move forward.

Developing a "Technology Portal" for Intellectual Property

To market its technologies available for licensing and its growing portfolio of IP, NREL is working with DOE to develop an Internet database, called the EERE Technology Portal (named for the DOE Office of Energy Efficiency and Renewable Energy, or EERE). The EERE Technology Portal will provide commercial access to publicly available, DOE-relevant IP information from NREL and other DOE national laboratories and universities. Current participants include Brookhaven National Laboratory, Idaho National Laboratory, the Pacific Northwest National Laboratory, Oak Ridge National Laboratory, the Battelle Memorial Institute, the Midwest Research Institute, the University of Colorado, Colorado State University, and the Colorado School of Mines.

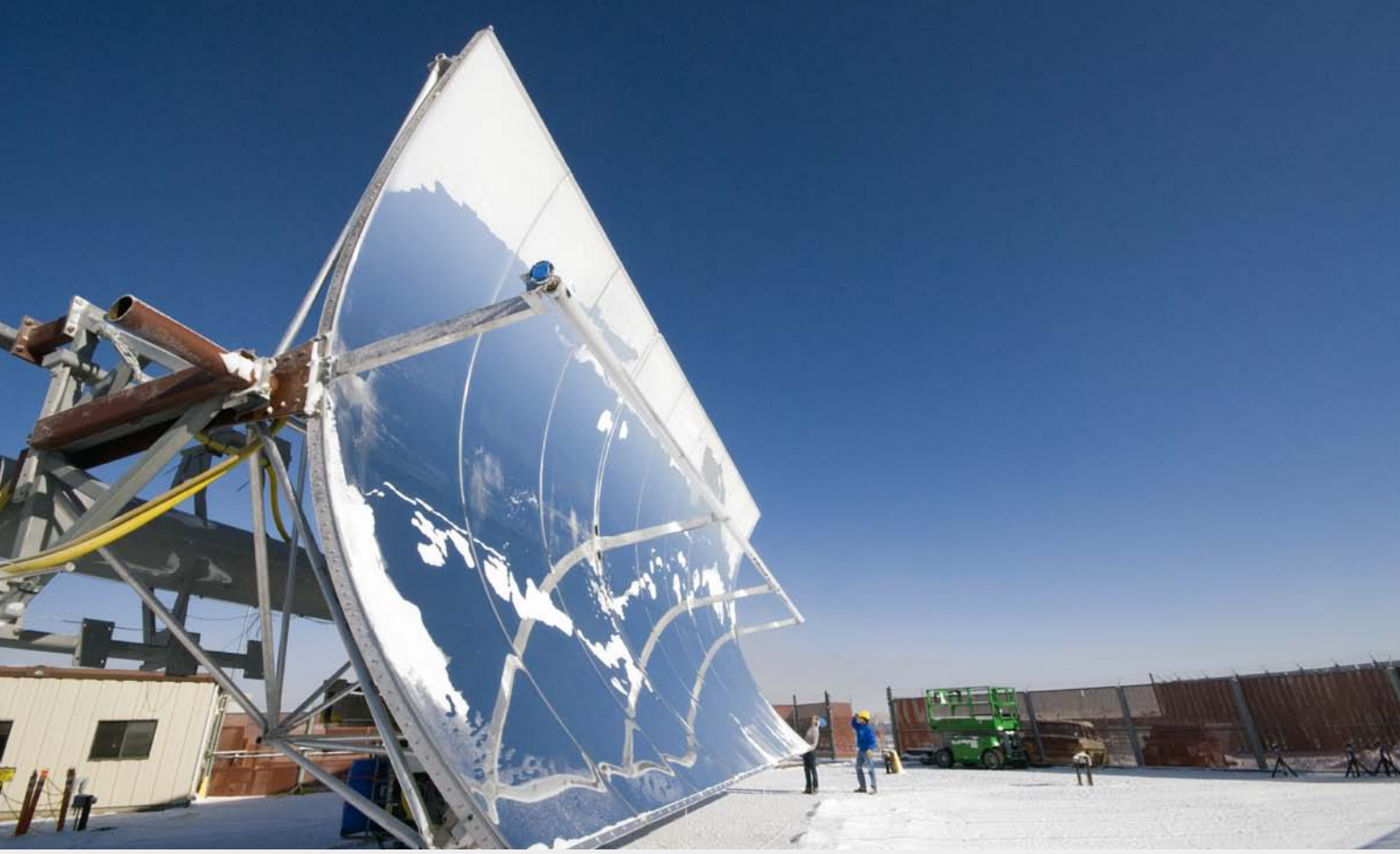
The portal will feature "one-stop shopping" for technology IP seekers. They will be able to streamline their search, foregoing the painstaking process of separately contacting each IP owner. Previously "orphaned" technologies, which on their own found no purpose, will be bundled with other technologies to become full solutions.

"The short course was a wonderful way to learn how researchers like myself can get our discoveries out into the marketplace, where they can make a real difference," says Chaz Teplin, a scientist with NREL's National Center for Photovoltaics.

Providing Funds for Technology Commercialization and Deployment

Through another DOE program—the Technology Commercialization and Deployment Fund (TCDF)—NREL has expanded its collaborative efforts between researchers and companies to develop commercial products based on NREL innovations. NREL researchers and companies submitted proposals for commercially beneficial projects, and projects were selected based on their fit with the program, the value of NREL's IP position, and the potential for near-term commercial impacts. Company partners share 50% or more of TCDF project development costs.

As of FY 2009, NREL has committed more than $4.4 million to TCDF projects. The lab's current TCDF portfolio includes Ampulse and Silexos, both of which are developing crystalline silicon solar cells; Greenvolts, which is developing an IMM solar cell for the company's proprietary concentrating system; Applied Optical Sciences, which is developing solar cells using thin-film silicon technology and is also aiming to commercialize an energy-efficient optical furnace; and Tau Science, which is commercializing an NREL-developed, quantum-based system for determining the conversion efficiency of solar cells.



NREL worked with SkyFuel, Inc. to develop the SkyTrough, a concentrating solar power system that employs lightweight materials to lower up-front costs, improve durability, and reduce maintenance needs (see page 10).
A new project will develop and test an abrasion-resistant coating for the reflective surface.

Tau Science aims to deploy the NREL technology in PV manufacturing lines.

Among CSP technologies, SkyFuel is developing an abrasion-resistant coating for ReflecTech® Mirror Film, currently marketed by the company, and conducting long-term testing of a SkyTrough CSP system that uses the abrasion-resistant coating. In addition, SCHOTT Solar, Inc. will commercialize NREL's advanced coating technology for heat-collecting elements in CSP applications, while Atlas Engineering will commercialize the award-winning rapid weatherization testing technology that was developed with NREL's help.

Other TCDF projects underway include Glocon's development and commercialization of an NREL-developed wind turbine blade profile for use in air-cooling applications; Nuclear Filter's validation of NREL's electrochromic hydrogen sensor; and Ventek's deployment of a near-infrared sensing technology in veneer production facilities.

To leverage the federal government's investment at NREL, the Alliance for Sustainable Energy also introduced a privately funded technology transfer program. Under the program, the Alliance partners will invest $1.75 million to fund basic patenting, marketing, and licensing activities. NREL will also use the funds to attract external investments, primarily for innovations developed under DOE programs.

Establishing the Venture Capitalist Advisory Board

Through the Alliance, NREL has also established a Venture Capitalist (VC) Advisory Board to provide advice and pre-staged access to capital.

The board will enable NREL to:

- Identify and foster technologies that can serve unmet market needs
- Form startup companies that can successfully raise financing
- Commercialize mission-relevant technologies faster
- Focus science efforts on the development of impactful technologies.

"As DOE dramatically increases its role in financing renewable energy development in the United States, it is more important than ever that they maintain an active and productive dialogue with the venture capital community to ensure that government dollars are being invested wisely," says VC Advisory Board Member Brad Barton of NGP Energy Technology Partners. "The NREL VC Advisory Board is essential in accomplishing that objective."

VC Advisory Board members served on the committee to select 34 companies out of more than 200 applicants to present at the 22nd NREL Industry Growth Forum. The forum serves as a platform for providing linkages between NREL, the investment community, and clean energy entrepreneurs.

NREL's Industry Growth Forum Helps Advance Clean Energy Companies

NREL's 22nd Industry Growth Forum attracted nearly 600 investors, entrepreneurs, scientists, and policymakers. The three-day forum, conducted in Denver, Colorado, on November 3-5, 2009, highlighted clean energy industry technology and business developments and featured new programs, such as seminars on partnering with the laboratory in research and commercialization agreements, as well as a "speed dating" format that helped entrepreneurs briefly meet with many potential investors.

At the forum, competitively selected company presenters—from early-stage startups to later-stage companies—receive feedback from investors on their business plans. In turn, investors learn about the potential investments and market trends in clean energy.

Three entrepreneurial companies were singled out from the 34 presenters to win a total of $20,000 in 2009 Clean Energy Venture Awards, which are sponsored by Deutsche Bank Climate Change Advisors. The cash prizes include $10,000 for Best Venture and $5,000 each for the two Outstanding Presentation Awards. NREL will provide the winners with in-kind commercialization support matching the cash award to help increase their chances of commercial success.

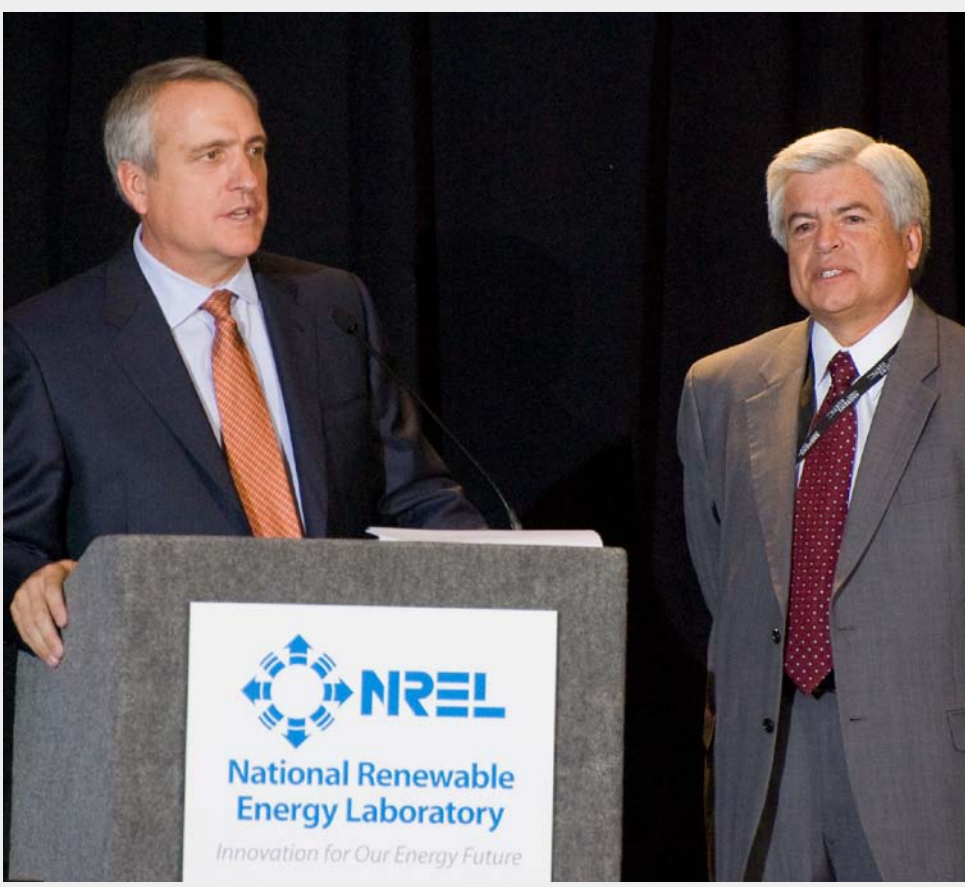
"We need to approach energy differently and the key will be innovation. This forum brings together the clean energy innovators, investors, and policymakers needed to bring about transformational change," says NREL Director Dan Arvizu.

Ecovative Design took the top prize. Ecovative creates compostable, bio-based products that can serve as insulation or can replace commonly used packaging materials such as Styrofoam.

Their manufacturing process uses about 10 times less energy per unit of material than the manufacture of synthetic foams using fossil fuels. And unlike other green packaging, their product can be custom-molded while also offering thermal protection.

"Winning the NREL growth forum is very important validation of our product and our company," says co-founder Eben Bayer, whose business was incubated while he and Gavin McIntire, the other co-founder, were students at Rensselaer Polytechnic Institute in upstate New York. "It changes how we are perceived by investors and the clean energy industry."

So far, Ecovative Design has received $1.15 million in grants and awards. The company is seeking $3.65 million in early-stage financing to build a scalable manufacturing plant closer to agricultural feedstock sources.

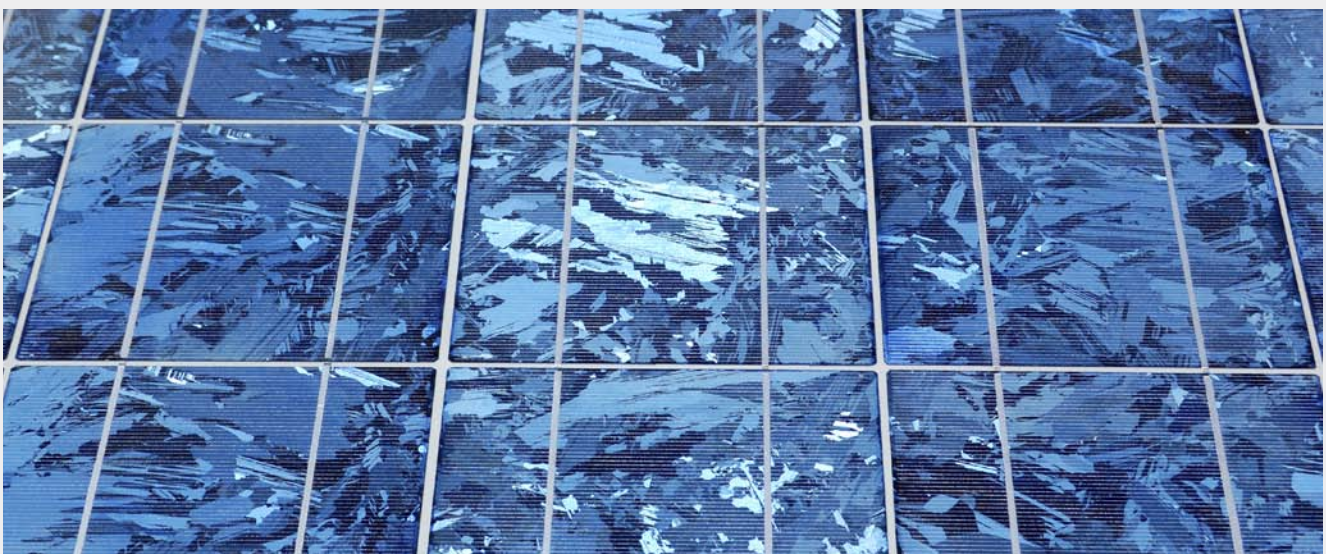


Colorado Gov. Bill Ritter, left, and NREL Director Dan Arvizu field questions about the clean energy economy at the 22nd Industry Growth Forum in Denver. The forum is organized by NREL.

In addition, Exro Technologies won an Outstanding Venture award for bringing to market a unique wind turbine generator that is capable of increasing the annual electricity produced by 10% or more, without increasing capital costs. The generator can also be applied to turbines that capture the energy of river and ocean currents and tides.

The second Outstanding Venture award went to Evolutionary Genomics for developing and successfully patenting a cost-effective technology platform that can identify the key genes that control fundamental traits of plants and algae, such as oil content. The firm has raised $7.7 million and is seeking another $3 million in financing.

Companies seeking financing at the Industry Growth Forum can draw some optimism from the forum's successful track record. More than $2.5 billion have been raised by the companies that have presented at the forum since its inception in 2003.



Computer Chip Leader to Take on Solar Cell Technologies

An important aspect of deploying clean energy technologies at speed and scale is for NREL to work closely with industry. As one indication of NREL's ties with industry, the laboratory signed 124 new cooperative research and development agreements (CRADAs) and work-for-others agreements in FY 2009 alone. The new agreements are valued in excess of $56 million. One example of the huge potential of such agreements can be found in a new CRADA with RF Micro Devices (RFMD), a global leader in the design and manufacture of semiconductor components for the computer industry.

By as early as 2012, a revolutionary semiconductor-based production process for highly efficient PV cells is expected to evolve from the July 2009 agreement with RFMD. The PV cell technology, developed by NREL, has achieved world-record solar conversion efficiencies of 40.8%, and it's anticipated that a higher efficiency will be achieved.

"We are very pleased to be collaborating with NREL to leverage our wafer manufacturing expertise and cost structure to manufacture high-performance PV cells available in high volumes, with quality and reliability, and at a greatly reduced cost," said Bob Bruggeworth, president and CEO of RFMD. "RFMD's industry-leading wafer fabrication capability and expertise in commercializing compound semiconductors, combined with NREL's technology leadership and decades of research, uniquely position us to accelerate the commercialization of this next-generation technology."

The involvement of this global manufacturing giant could cause a significant shift in the solar manufacturing industry. The multiyear CRADA project will be accomplished at RFMD facilities in Greensboro, North Carolina, in three phases, leading to production readiness for the large-scale manufacturing of high-performance PV cells with high reliability and low cost.

COMMERCIALIZATION & DEPLOYMENT

Deployment & Industry Partnerships

NREL's Integrated Deployment team has a goal of facilitating and accelerating the widespread deployment of renewable energy and energy efficiency technologies throughout the United States and around the world—a goal that cannot be achieved from afar. Increasingly, NREL's deployment activities have required NREL staff to branch out from the lab environment and provide sustained technical assistance in places where putting energy innovation into action is a top priority.

Rebuilding Green in the Heartland

One such place is Greensburg, Kansas. After an EF-5 tornado ripped through the town of 1,400 in May 2007, destroying 90% of the city's buildings and infrastructure, NREL's Integrated Deployment team worked with DOE support and subcontractors on the ground to help the town fulfill its vision of rebuilding as a model green community. In the two years since the disaster, Greensburg has made extraordinary progress toward realizing its vision. The community has started rebuilding and maintains a firm commitment to residential and commercial energy efficiency and locally generated renewable energy. Should the town meet the robust energy goals outlined in the Greensburg Sustainable Comprehensive Plan, which are based largely on NREL studies and guidance, it is headed for a 36% reduction in carbon dioxide emissions from pre-tornado levels.

In 2009, NREL continued to build on these successes in Greensburg by focusing on a formalized effort to win strong community support for residential green building. Based on NREL's recommendations, Greensburg partnered with the Kansas Building Industry Association in May

A Sustainability Plan for Greensburg, Kansas

With guidance and expertise from NREL, the town of Greensburg, Kansas, has put together a comprehensive sustainability plan and has already achieved these impressive milestones:

- *A formal commitment to rely on locally generated renewable energy.* After ending a long-term power purchase agreement with a coal-based rural electric cooperative, Greensburg entered into a contract with the Kansas Power Pool, a power provider that focuses on developing renewable energy generation sources and has committed to offering "100% renewable electricity, 100% of the time." The Kansas Power Pool and John Deere Renewable Energy have committed to build a new 12.5-megawatt wind farm on the outskirts of Greensburg. The city has also adopted new regulations for distributed solar and wind generation, including a net billing policy, a model agreement for grid interconnection, and ordinances to encourage solar and wind power.
- *A resolution to build all city-owned buildings to LEED Platinum standards.* Inspired by the city's commitment to energy-efficient building design, other public and commercial buildings, including the local school and hospital, have followed suit. As a result, Greensburg is on track to have the highest concentration of LEED Platinum and Gold buildings in the country.

The Kiowa County Memorial Hospital expects to be the first LEED Platinum Critical Access hospital in the United States, opening in early 2010.

2009 to establish the Greensburg GreenHome Program. Using as a guide the National Green Building Standard, which was adopted by the International Code Council in January 2009, the voluntary program is designed to encourage growth and rebuilding, while also promoting higher energy efficiency and green performance.

"When any community wants to build green, there are lessons that need to be learned," says NREL project leader Alex Dane. "GreenHome is creating the learning curve."

Since GreenHome was launched, NREL's Integrated Deployment team has been busy clearing the path for a successful rollout. The team has worked on local outreach to educate builders, homeowners, and city leaders about energy efficient building codes—their purpose, the ins and outs of their implementation, and the benefits they can provide.

Dane believes the voluntary nature of the program—and the outreach and training it will provide in the months ahead—opens the door for builders, homeowners, and city leaders to become comfortable with green building.

With help from NREL and DOE, Greensburg is getting a fresh, new start. To show their appreciation, city leaders recently recognized NREL and DOE with the city's first Outstanding Support Award for playing an "instrumental" role in the town's recovery.

"NREL has made our lives easier and better," said City Administrator Steve Hewitt. "Our experience will benefit many other communities that NREL will be working with."

Supporting Proactive Clean Energy Initiatives in Outlying Areas

In addition to establishing a framework to help devastated communities rebuild, NREL's work in Greensburg is already serving as a roadmap for more proactive energy initiatives on a broader scale. The same strengths that provided aid in the aftermath of disaster in the heartland are assisting forward-thinking efforts to increase energy security in the farthest reaches of the United States—from Hawaii and the U.S. Virgin Islands to Alaska. Because of their remote locations and almost exclusive reliance on fossil fuels, these places incur higher-than-average energy costs.

Charting a New Course Toward Energy Independence for Hawaii

In Hawaii, imported oil supplies 90% of the state's energy needs,

threatening both the environment and economy. Fortunately, the state has an abundance of renewable energy resources, providing a means to reduce the imbalance.

Recognizing that Hawaii needed to tap its indigenous resources to create a more sustainable energy strategy, the state's leaders turned to DOE to help launch the Hawaii Clean Energy Initiative in 2008. The initiative's goals are as sweeping as the vistas of Hawaii's shorelines: Through a combination of energy efficiency efforts and renewable energy development, the state wants to meet 70% of its energy needs with clean energy by 2030.

As the state of Hawaii began charting a course to meet this ambitious clean energy goal, the state energy office turned to NREL's Integrated Deployment team for help. The plan that emerged called for cutting energy use by 30% and sourcing 40% of Hawaii's energy from renewable resources, including solar, wind, geothermal, biomass, ocean, and hydroelectric energy. It's a complex undertaking, making it difficult to manage remotely from the lab's Colorado campus.

In 2009, NREL established a presence in Hawaii, which leveraged the lab's knowledge and experience more effectively to help the state of Hawaii navigate largely uncharted waters. Policy analysis provided by NREL's Integrated Deployment team helped drive critical legislative measures, clearing the way for the initiative to move forward. In addition, the NREL team assisted with technical research and analysis to identify where the greatest potential for energy savings and renewable energy development exist.

"To accomplish something on the ground, you have to have experts on the ground," says Mary Werner, NREL's executive manager of Integrated Deployment. "Being there in real time is a critical piece in getting a community—or an entire state—to move in the same direction toward its renewable energy goals."

NREL's Paul Norton is now working with Hawaii's State Energy Office, while NREL's Debra Lew is helping Hawaii's utilities learn how to integrate wind and solar power into their electrical grid and to manage the effects of these variable resources on utility operations and costs. The pairing of two of NREL's top technical experts is fortuitous, because the two are also married.

As the Hawaii Clean Energy Initiative gains momentum, NREL will continue providing local, on-the-ground project-development support—including energy analysis, strategic planning, education, training, partnership building, and risk mitigation—to help Hawaii meet its clean energy goals.

Hawaii is rich in renewable resources, with fertile lands for biomass, ample sunshine for solar power, strong sea breezes for wind power, an active geology for geothermal energy, and the constant energy of the surrounding ocean, which can provide seawater cooling and power.

Advancing Alaska's Renewable Energy Industry

At first glance, Alaska could not be more different from Hawaii: arctic and huge versus tropical and small. Yet from an energy perspective, it faces similar challenges: soaring energy costs and a heavy reliance on fossil fuels. On the other hand, it too has significant renewable energy resources that present an extraordinary opportunity to improve the situation. That is why NREL's Integrated Deployment team is clearing the path for a major Alaskan energy initiative that will ramp up renewable energy development and energy efficiency efforts in the nation's largest state.

Currently, NREL is focusing the bulk of its efforts on remote rural

Supporting Alaska's Shift to Clean Enegy

To help Alaska prepare for an economic transition driven by clean energy, Brian Hirsch is leading NREL's effort to advance the state's renewable energy industry. That work includes coordinating government agencies, communities, and developers; providing technical training and assistance in energy planning; helping to advance biomass and wind-diesel hybrid technology initiatives through DOE tribal programs; providing education and outreach within tribal communities and among the broader public; and offering guidance to support funding opportunities and inform decisions on Recovery Act funds. As the pieces of the puzzle come together, Hirsch is working with DOE, tribal and community leaders, and developers to establish overarching energy goals for the Alaska initiative and to outline a strategy for achieving those goals.

areas of Alaska, where the potential to improve the energy picture is the greatest. Because of the state's poor infrastructure and harsh climate, rural Alaskans consume the most energy per capita in the country—and they also pay the highest prices. Ironically, although Alaska is well known for its abundant fossil fuel resources, those resources do not translate to cost savings for the people of Alaska. NREL project leader Brian Hirsch points to one rural community that sits 100 miles from America's largest oil field, and yet the people who live there pay as much as $12 a gallon for gas and $1.25 per kilowatt-hour for electricity.

Fortunately, Alaska also has abundant renewable resources. The Electric Power Research Institute estimates that the state holds up to 80% of the tidal energy potential and 50% of the wave energy potential of the entire United States. According to Hirsch, even a small portion of that energy would be sufficient to power all of Alaska and leave substantial excess for export. Alaska also has considerable commercial-scale wind and biomass energy resources, significant solar and hydropower resources, and world-class geothermal resources.

"Over the long term," says Brian Hirsch, " there is tremendous potential for developing renewable energy that will support vibrant communities, a healthy environment, and a prosperous economy."

Alaska has already taken a leadership role in harnessing its renewable resources through DOE programs such as Wind Powering America. Now NREL is joining forces with DOE and local communities to build on that momentum in Alaska.

Demonstrating the Energy Security of Clean Energy on Military Bases

If NREL can help an entire island become energy self-sufficient, or help a state as big as Alaska, surely it can help military bases achieve energy independence as well. That's the thinking behind a new DOE initiative with the U.S. Department of Defense (DOD). DOD recognizes that its military bases are dependent on outside energy sources, in particular the local power grids, and actions to reduce that dependence will increase the energy security of U.S. military bases. With that in mind, the new initiative aims to create military installations with a net-zero-energy use, choosing the Marine Corps Air Station (MCAS) in Miramar, California, as the initial pilot site.

Miramar is starting with a strong focus on energy efficiency. Under an Energy Savings Performance Contract, the air station is getting heating and cooling upgrades, a 2.5-megawatt combined heating and cooling system, and an 8-megawatt backup power system. All new buildings will be highly energy efficient, and the station is using biodiesel and compressed natural gas in many of its vehicles. Miramar is also integrating solar energy in its buildings and hot water systems and is preparing to buy power generated

One energy conservation measure implemented by MCAS Miramar is solar-powered parking lights. The Secretary of the Navy awarded MCAS Miramar the 2009 Energy and Water Management Award.

from landfill gas at an adjacent landfill.

These base-initiated energy projects have put MCAS Miramar on track to achieve a 43% reduction in building energy consumption by 2012. An additional implementation plan developed by NREL in collaboration with the Federal Energy Management Program (FEMP) would enable the base to achieve net-zero electrical energy and a 90% reduction in building energy consumption by 2015. Miramar's emphasis on improving energy performance and its demonstrated commitment to achieving the net-zero-energy goal have earned it the distinction of being designated the first Green Marine Corps base.

Using the MCAS Miramar project as a model, NREL and FEMP are creating a standardized process that other military bases can follow as they work toward attaining net-zero-energy status. The DOD is planning to replicate the project at many of its facilities, with assessments already underway at the U.S. Air Force Academy in Colorado, the U.S. Army Pohakuloa Training Area in Hawaii, and multiple U.S. Navy sites.

These extremes—from disaster recovery strategies that integrate clean energy technologies to proactive clean energy initiatives designed to increase energy security—illustrate the wide range of capabilities NREL's Integrated Deployment team brings to a vast and varied landscape. But this integrated approach is not just about dealing in the extremes; it's about leveraging NREL's wide-ranging skills to address long-term energy solutions for our nation's everyday needs.

Working with Industry: Partnerships for Energy Innovation

While deploying clean energy technologies involves action and extension, partnering with businesses outside the laboratory creates synergies that have the potential for extraordinary innovation. In FY 2009, NREL participated in or led a variety of programs that resulted in such innovation. NREL is weaving a broad network by collaborating with industrial companies, academia, government agencies, and diverse businesses. Whether facilitating projects, fostering workforce development, or expanding infrastructure, NREL lends expertise that is helping to increase adoption of renewable energy and energy efficiency technologies nationwide.

Paving the Road to Economic Recovery

With the goal of expanding development of renewable energy projects throughout the nation, DOE and the U.S. Department of Treasury are collaborating on a program that makes direct payments—instead of tax credits—to companies that create renewable energy properties and place them in service. Between the two agencies, this effort will add up to at least $3 billion in financial support to businesses through the American Recovery and Reinvestment Act. The support will stimulate the construction of about 5,000 facilities that draw on biomass, solar, and wind energy, as well as other renewable energy resources.

This is promising news for renewable energy investments and for the U.S. economy; but it's a

Indiana already has enough wind farms under construction to meet its goal of reaching 1000 megawatts of wind power capacity by the end of 2010.

tall order that requires the kind of expertise NREL has to offer. To help ensure its success, DOE and the Treasury Department enlisted NREL to manage the project. Misty Conrad, of NREL's State, Local, and Tribal Program, took on the task of managing the program infrastructure.

Conrad and her team have put their experience to work by developing guidance, terms, and conditions for the direct payments. A Web-based application system has helped to streamline the whole process for applicants and federal agencies. NREL is also providing technical reviews of applications and devising reporting mechanisms, including a daily reporting system to update DOE and the Treasury Department on the status of the applications.

Conrad expects the work on this project to continue for at least four years, so having the right system to manage applications is proving useful to quickly distribute money where it is needed. As of the end of FY 2009, the program had already made 37 awards, totaling more than $1 billion.

"That's billion with a 'b'!" says Conrad.

Fostering Wind Energy in Indiana

Historically, the state of Indiana has been called the "coal state"—that is until NREL got involved. In just two short years, Indiana has gone from zero to more than 500 megawatts of installed wind energy capacity. NREL is helping the state work toward a goal of having more than 1,000 megawatts of wind power capacity by the end of 2010. That would create a total of $1.3 billion in economic benefits to Indiana's economy, while reducing carbon dioxide emissions by 3.1 million tons annually and saving more than 1.6 million gallons of water each year.

An updated wind resource map completed by NREL researchers showed much more resource potential at 70 and 100 meters above ground than previously indicated by 1980 maps. This realization helped foster wind energy development in the state, as Indiana and NREL's Wind Powering America working group helped pave the way for utility-scale wind energy projects.

Indiana is now home to two utility-scale wind projects and the largest wind power plant east of the Mississippi River. The 130-megawatt Goodland I Wind Plant in Benton County and the 400-megawatt Fowler Ridge Wind Farm in Benton and Tippecanoe counties employed more than 400 people during their construction and will create about 24 full-time jobs. In total, Indiana now hosts 11 wind manufacturing facilities that employ more than 1,000 people. An additional 505 megawatts of wind power development is underway in 15 counties, not only adding wind capacity but also further expanding Indiana's green collar workforce.

With continued support from NREL, there is a new breeze blowing in Indiana and other states to increase the adoption of wind energy resources across the nation.

Providing Convenient, Effective Online Training for Clean Cities Coordinators

The 87 coordinators who lead DOE-supported Clean Cities coalitions across the United States are working hard to enlist companies in their communities to cut back on the amount of gasoline and diesel used by their vehicle fleets. Clean Cities coordinators need to be well versed in a variety of technologies and tools to accomplish their mission, yet they often lack the time and funding to attend training classes locally, let alone out of state. Looking to provide coordinators with thorough, effective training

By encouraging the use of biodiesel, Clean Cities can help heavy trucks reduce their particulate emissions and their reliance on petroleum.

that is both convenient and cost-effective, DOE turned to NREL for a solution.

NREL responded with Clean Cities University (CCU), a virtual solution that allows coordinators to receive training from the comfort of their desks at any time of day. Launched in September 2009, CCU is an online training program that educates Clean Cities coordinators about various petroleum-reduction technologies and tools. CCU courses have three tracks: Clean Cities' e-Tools, professional development, and vehicle and fuel technologies. Each track comprises a series of courses from which coordinators can select, based on their specific areas of interest. Tailor-made for Clean Cities coordinators, the courses enable them to apply the training to their day-to-day work. Under the 2010 Coalition Support Contract, coordinators are required to complete four CCU courses annually. Those who choose to take more receive special recognition for going above and beyond the required course load.

Within two weeks of the CCU Web site's launch, a third of Clean Cities coordinators had already logged on and begun taking courses. Initial feedback was overwhelmingly positive, with coordinators reporting that the system works well and describing courses as user friendly, well timed, and helpful.

Mentoring Businesses for Success in Clean Tech

As a renewable energy and energy efficiency leader, NREL is known for providing technical expertise to help businesses and governments adopt new technologies. But these days, NREL is reaching out to small energy-related companies and offering expertise that can help them enhance their business practices and technical capabilities. NREL's Mentor-Protégé Program is a DOE initiative to encourage small businesses to become successful subcontractors not just with NREL, but also with DOE, other federal agencies, and private industries.

The Mentor-Protégé program was successfully launched in 2009 and two agreements are now in place. The first is a partnership with New West Technologies, a small Native American-owned business that specializes in engineering and technical services. The second is with St. Andrews Construction Services, a small Hispanic American-owned business specializing in construction and electrical services.

"A lot of work went into finding protégés that fit NREL's mission," said Nancy Gardner, NREL Small Business Partnership Manager. "After successfully achieving this goal, I'm optimistic that our Mentor-Protégé partnerships will continue to grow and prosper for both the lab and each protégé that we bring on board."

According to Gardner, the goal is to support seven mentoring efforts over the term of NREL's prime contract. But with two already underway in the first year of the program's implementation, she expects the program to substantially exceed that goal. This and other efforts helped Gardner receive an "advocate of the year" award from the Rocky Mountain Minority Suppliers Development Council (see page 45).

STRATEGIC ANALYSIS

NREL's strategic analysis capabilities are intended to increase the understanding of the current and future impacts and interactions of energy policies, markets, resources, technologies, environmental effects, and infrastructure. These analyses are critical in informing decisions as energy efficiency and renewable energy technologies advance from concept to commercial applications.

STRATEGIC ANALYSIS

Laying the Analytic Foundation for Clean Energy Growth

The past year has been a banner one for renewable energy, with rapidly increasing demand for NREL's technologies and knowledge. And with that demand comes a great need for credible information on the broad technical, policy, and market issues involving renewable energy. The laboratory's analysts have been at the forefront of delivering data and analyses that help inform ever-increasing policy and investment decisions—and, ultimately, lead to change.

NREL has taken a three-pronged approach to increasing the value of its energy analysis. In 2009, the lab focused on strengthening its analytic foundation, taking great strides in integrating its analytical capabilities across all technologies and programs while ensuring consistency in analytical results. As part of a lab-wide effort, NREL also increased staff in areas such as economic analysis, which allowed the laboratory to look more closely at timely topics, such as the effects of renewable energy on job growth. NREL's models and tools, such as the Regional Energy Deployment System (ReEDS) model, also continued to evolve—ReEDS is now recognized as one of the premier models for evaluating electric-sector transformation, with particular representation of renewable energies.

During a time when social media and increased forms of electronic communication have made data on energy more accessible, NREL has strengthened its capabilities to disseminate its information to the outside world. The lab's digital assets are key for decisions that will transform our world's critical energy systems. This sharing of information will also help strengthen communication with government, industry, and other partners.

The past year has shown that a carbon-neutral world depends on a transformation of policy as well as an investment in a renewable energy future. NREL's analysis will be central to determining what path to take.

NREL has always seen its analysis as a first step in informing research, investment decisions, and policy at all levels. And in 2009, the lab moved to make that foundation even stronger.

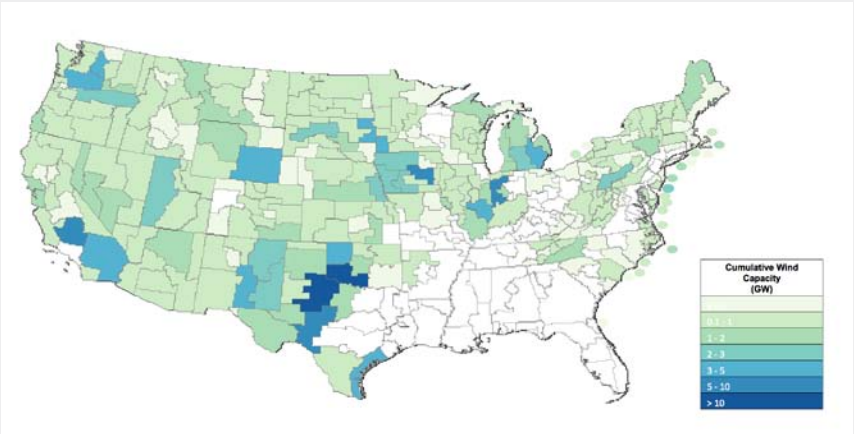
"We know that analysis needs to happen every step of the way when you're trying to take renewable energy technologies from innovation to commercialization," said Bobi Garrett, Senior Vice President for Outreach, Planning and Analysis. "Analysis is critical at each decision point."

During this ongoing process, NREL analyses rely on expertise in several areas: resource availability and characteristics; technology and component performance and cost; system performance and technology interfaces related to the overall system; benefits and impacts of programs, portfolios, markets, and policy options; complex decisions under uncertainty and risks; life-cycle assessment; and environmental and climate effects, both local and global.

NREL's climate policy and carbon analysis are key to understanding how renewable energy and energy efficiency technologies—and our supporting research and development activities—can contribute to national and international goals to reduce carbon emissions.

The lab's analysis during 2009 helped the U.S. Congress understand the impact of proposed climate change policies and legislation. NREL's analysis also supports international climate dialogues, such as work being done for the Intergovernmental Panel on Climate Change. Energy models can be used to analyze climate legislation and provide an initial analysis of potential interactions among carbon policy options and existing incentives.

Renewable energy was definitely a hot topic during 2009. With new national energy legislation being considered, NREL used its ReEDS model to evaluate three proposed national renewable electricity



This map was created using NREL's Regional Energy Deployment System (ReEDS) model. It shows what effect a carbon cap (80% reduction) would have on wind capacity in 2050. In 2009, NREL used ReEDS in several analyses, including an evaluation of three proposed national renewable electricity standards.

standards and to look at the varied effects of other national energy, environmental, and economic recovery plans.

ReEDS is a computer model that optimizes the regional expansion of electric generation and transmission capacity in the continental United States over the next 50 years. Along with numerous independent analyses, ReEDS was used prominently for the 20% Wind Energy by 2030 report and is currently being applied to the Renewable Electricity Futures Study—an analysis of how the United States might provide 80% of its electricity from renewable sources.

As a result, two NREL analysts were invited to discuss their work at a congressional briefing.

During a time of economic downturn, the lab also examined how the economy affected investments in renewable energy, while providing information on financing solar projects.

Job loss—and job development—was on everyone's minds during this past year. NREL analysts used the laboratory's Job and Economic Development Impact (JEDI) models to look at how clean energy technology development, deployment, and related policies could enhance job creation.

NREL analysts also used the laboratory's Solar Advisor Model (SAM) to examine wind and solar potential in the western United States. The Western Wind and Solar Integration Study evaluated the technologies' contributions to reliability and capacity in the region. NREL analysis helped stakeholders identify priority Renewable Energy Zones for fast-track development.

Internationally, NREL is working with partners to help improve air quality and study the associated health benefits. The analysis is focusing on how renewable energy can help provide electricity in areas where grid expansion is not economically viable, reaching some of the 1.6 billion people in the world who don't have access to electricity. Using NREL's GeoSpatial Toolkit, a resource assessment tool, the lab provided countries such as Bhutan and Afghanistan with analyses that outline their renewable resources and demonstrate how they can optimize them.

NREL performed an assessment of the use and impact of sustainable biomass resources in Liberia, especially targeting the expansion of current resources and the potential of a new energy crop—Jatropha. Jatropha bears oil-rich seeds that can be used for biodiesel production, and it grows well on marginal lands—those characterized with poor climate and physical characteristics. The lab's analytical capabilities allowed analysts to quantify these marginal lands and evaluate the quality of biomass resources that could be produced there.

NREL analysts also conducted a life-cycle assessment of the federal renewable fuels standard (RFS), which requires the use of 36 billion gallons of renewable fuels in the United States by 2022. The analysis examined the environmental emissions attributed to ethanol production under the RFS, not including land-use impacts. The study found that the expanded level of ethanol production in 2022 will offer substantial benefits over conventionally produced gasoline in both net energy value and greenhouse gas emissions for multiple biomass feedstocks and conversion technologies.

In 2009, as part of a long-term effort, NREL became part of the collaborative Renewable Electricity Futures Study, which will explore clean electricity futures in three areas: renewables, nuclear, and low-carbon fossil. Laboratory analysts will lead the renewables effort by designing case studies that explore low-carbon electricity generation. Using NREL models, the team is evaluating the technical, economic, and environmental feasibility of a 2050 scenario where 80% of electricity is generated from renewables—results will be published in 2010.

Informing Decisions to Transform Energy Systems

State-of-the-art analytical modeling starts with a software capability carefully programmed to make use of various inputs to produce a variety of outputs. In energy analysis,

NREL's models and tools are used to inform decision-making in all facets of energy adoption:

- financial and technical performance of technologies
- multisite and multitechnology financial screening and optimization
- hybrid system economic and financial analysis
- geospatial technology and resource planning
- analysis of the impacts of policies and research and development goals
- planning energy systems and infrastructure.

"We don't always have the answers, but we can create the tools to find those answers," says Bobi Garrett, NREL's senior vice president of outreach, planning, and analysis.

In 2009, NREL debuted its Virtual Information Bridge to Energy Efficiency and Renewable Energy, or VIBE. Started in 2008 as an information portal, VIBE is based on existing energy tools and data developed by NREL and DOE. It is designed to provide greater access to energy data, tools, and results from models to help meet the great demand for timely, accurate, complete data to inform energy researchers, investors, policymakers, and consumers.

"We want to be the world's premier energy data hub," says Debbie Brodt-Giles, manager of the VIBE project. "Our 'open community' allows users to share data, which adds major value to NREL's own information."

The core platform allows large data sets to be housed at NREL and accessed and used by the world. Many DOE technology programs are now working with VIBE analysts to get their data and tools integrated into the platform.

VIBE has become the new way to drive traffic to existing tools and information. By leveraging the world's knowledge network, the lab can increase efficiency and effectiveness, using multiple analysis modules. Through this open access, NREL has also emphasized the need for total transparency of information, as well as the importance of collaboration.

NREL Senior Vice President Bobi Garrett (left) and NREL Director Dan Arvizu (right) congratulate the newly appointed executive director of the Joint Institute for Strategic Energy Analysis, Doug Arent (center).

The Joint Institute for Strategic Energy Analysis Names Executive Director

Doug Arent has been appointed executive director of the Joint Institute for Strategic Energy Analysis (JISEA) in January 2010. He was formerly director of NREL's Strategic Energy Analysis Center.

In 2009, NREL formed JISEA, which pulls together world-leading analytical capabilities from NREL and a number of universities to conduct analyses of complex energy issues that are beyond the reach of a single institution. The institute includes NREL, Stanford University, the Massachusetts Institute of Technology, the Colorado School of Mines, the University of Colorado-Boulder, and Colorado State University.

Following the highest standards for analysis, the institute's charter emphasizes addressing all energy resources and technologies on an equitable basis, with no bias toward political or sponsor positions. Ultimately, this guidance ensures that the analysis is technically sound and of the utmost value.

The workforce of tomorrow is also an institute priority. It is using its programs and interaction mechanisms to expand education and development opportunities for students, faculty, and analysis professionals. There are opportunities for staff exchanges, sabbaticals, internships, fellowships, and joint appointments. The exchange program was initiated in 2009 with a one-year assignment for an NREL employee at Stanford.

"The Joint Institute offers tremendous opportunity for NREL and its partners to provide credible and objective insights to help accelerate the transition to a sustainable energy economy," says Arent. "I am honored to be appointed as the executive director and look forward to an exciting and productive year."

COMMUNITY

At NREL, community involvement begins with its employees. Throughout 2009, employees gave their time, money, and energy to help the community. They were backed by a commitment from the Alliance for Sustainable Energy to provide financial support that allowed NREL to work in community organizations, support local economic development efforts, and educate teachers, students, and consumers about renewable energy and energy efficiency.

COMMUNITY

Working with the Community

NREL employees opened their hearts and pocketbooks this year, pledging more than $180,000 to local community-service agencies through the laboratory's Charitable Giving Campaign.

That was enhanced by a contribution from the Alliance, raising the total to more than $200,000. NREL's charitable giving campaign was recognized by Colorado Community Shares as one of the best of the year among all Colorado campaigns.

Yet another community service project organized by NREL volunteers was a workshop to teach low-income families how to gain assistance with their energy bills. The "High Energy Assistance" event in inner-city Denver taught 75 families how to save energy and forged ongoing partnerships with the Association of Blacks in Energy, Colorado Human Services, and the Colorado Energy Assistance Foundation.

Community Engagement

While NREL is a long-standing member of many area business chambers of commerce, it particularly emphasizes its outreach to diverse business and community organizations such as the Black, Asian, Indian, and Hispanic Chambers of Commerce. This year, NREL hosted a networking event for 100 members of the Rocky Mountain Minority Suppliers Development Council to encourage them to do more business with the federal government. The council recognized NREL's Nancy Gardner with its "advocate of the year" award for her outstanding contributions. NREL's participation in a regional government procurement conference, as well as an NREL event for Latina and Asian Chamber members, helped educate potential suppliers about how to work with NREL and DOE.

Local Economic Development

NREL's engagement with statewide business, government, and community leaders was at an all-time high this year. Economic and community outreach activities ranged from forums for the Metro Mayors' Caucus to visits by Colorado's Congressional Delegation and tours of NREL by economic development organizations, workforce boards, and municipal planning committees.

NREL's highly successful Executive Energy Leadership Program, or "Energy Execs" for short, had 31 participants from city, county, state, and corporate organizations. In its third year, the value of Energy Execs is underscored by continued relationships between the laboratory and alumni—including those with ProLogis and C.B. Richard Ellis.

To expand NREL's reach into the local business community, the Alliance made a three-year, $10,000 commitment to the Metro Denver Economic Development Corporation and participates on its executive committee and that of the Colorado Energy Coalition. NREL actively engages with Colorado business organizations in efforts to accelerate the adoption of clean energy.

Education

Workforce development was at the forefront of NREL's emphasis on education in 2009. A record number of student interns were brought into the laboratory work environment to help develop the scientists and engineers of the future.

Another 10,000 students and teachers learned about renewable energy this past year from NREL's Renewable Energy and Energy Efficiency Education on Wheels (RnE2EW) project. RnE2EW is a mobile clean energy classroom that delivers hands-on curriculum and learning to schools and at events throughout Colorado, as well as in several other states. The traveling bus and NREL's education staff delivered programs to more than 26,000 students, teachers, and consumers in FY 2009.

NREL's support for science education extended to several student competitions that encourage middle and high school students to love science and choose it as a career. The NREL education office organized the Colorado High School Science Bowl, the Junior Solar Sprint, and Hydrogen Fuel Cell car competitions, and played an integral role in DOE's National Science Bowls for high schools and middle schools. These programs reach thousands of students across the nation each year.

Public Outreach

The NREL Visitors Center is central to much of the lab's interaction with the public. Not only is it the "front door" to thousands of visitors to the laboratory each year, it is an educational resource for consumers, teachers, and students. In 2009, the center served about 17,000 visitors through tours and educational programs. The addition of the Science on a Sphere exhibit attracted many new visitors with its three-dimensional programs about energy's impact on the world.

Developed at the National Oceanic and Atmospheric Administration, the Science on a Sphere exhibit at NREL's Visitor Center provides three-dimensional information about energy and climate.

Monthly consumer programs on hot new research topics and simple how-to instructional courses are regularly attended by hundreds of people.

NREL worked closely with its neighbors in 2009 as fast-paced construction on the lab's main campus and at the National Wind Technology Center began to attract attention. Construction of two utility-class wind turbines at the wind site quickly became iconic symbols for nearby neighbors and commuters, while the Research Support Facilities rising on the main campus attracted the interest of nearby homeowners. Through regular community newsletters, an information hotline, a construction Web site, and two community meetings, the laboratory reached out to more than 8,000 neighboring households and businesses to inform them about NREL's growth and research successes.

NREL's Executive Energy Leadership Program participants visit Colorado State University's Engines Laboratory to learn about bioenergy and engine design and performance research. From left: Jim Benson, Carol Tombari, Jim Bosch, Scott Prestige, Irene Pérez Law, Tom Acre, Frank Phillips, Scott Randall, Virgil Turner, and the Engines Laboratory representative.

The National Renewable Energy Laboratory (NREL) is the nation's primary national laboratory for renewable energy and energy efficiency research and development. NREL is operated by the Alliance for Sustainable Energy, LLC for the U.S. Department of Energy (DOE). DOE's Office of Energy Efficiency and Renewable Energy is the primary funding source for NREL, with additional funding from the DOE offices of Basic Energy Sciences and Electricity Delivery and Energy Reliability.

This year's Annual Report staff includes Kim Adams, Karen Atkinson, Bryan Bechtold, Kevin Eber, William Gillies, Terri Jones, Michelle Kubik, Theresa von Kuegelgen, Kerry Masson, Karen Petersen, Kathryn Ruckman, Michelle Sosa-Mallory, and Ernie Tucker.
Kevin Eber was the lead writer and editor for this publication, and it was designed by Bill Gillies.

The NREL Annual Report is produced in-house by the NREL Communications and External Affairs Office. It is also available online at www.nrel.gov/docs/fy10osti/45629.pdf

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

NREL/MP-6A4-45629 • January 2010

Printed with a renewable-source ink on paper containing at least
50% wastepaper, including 10% post consumer waste.