NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Energy Innovations
Science & Technology at NREL

Summer 2010

In this issue, we highlight building efficiency and renewable fuel advances.

NREL a leader in advanced biofuels production technologies

New high throughput platform speeds up biomass analysis

NREL publishes largest wind integration studies

and more.

Published by the National Renewable Energy Laboratory

NREL's Research Support Facility and its Foundations in Energy Efficiency

The Research Support Facility (RSF), an ultra-efficient office building that opened in June on the U.S. Department of Energy's (DOE) NREL campus in Golden, Colorado, has a foundation in energy efficiency, grounded in the work of NREL's commercial buildings team. Long before crews broke ground on the future home of 800 staffers in May 2009, NREL's buildings experts had distilled years of knowledge into an exacting 506-page Request for Proposals (RFP) for DOE to use in its selection of a design-build team for the $64 million project.

The Buildings Research Program at NREL has a 30-year history of developing tools, technologies, and techniques to create ultra-energy-efficient buildings for government and industry. NREL's buildings researchers focused on developing an energy goal for the RSF using Opt-E-Plus, an NREL-developed computer tool that models and helps to minimize energy consumption. After exhaustive analysis aimed at producing a 219,000-square-foot national prototype, they determined the RFP's core would be an energy-efficiency standard of 25 kBtu/sf/year—a third of the energy usage in conventional commercial buildings.

"We set the energy efficiency requirement and everything in the RSF has cascaded from that number," said Ron Judkoff, manager of NREL's Buildings Research program.

Following selection of the winning design-build team, Haselden Construction and RNL Design, NREL's researchers worked collaboratively to reach the aggressive efficiency target. This was a pioneering effort, going beyond LEED Platinum, the highest designation by the U.S. Green Building Council. Throughout the process NREL researchers Paul Torcellini and Shanti Pless provided energy guidance in key areas such as whole-building

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The main entrance to the new RSF with the view facing west.

Heather Lammers/PIX17513

Achieving Energy Efficiency through Retrofits

"Improving the efficiency of buildings, which account for 40% of U.S. energy use, is truly low-hanging fruit," DOE Secretary Steven Chu wrote recently in a report titled *Energy Vision 2010: Towards a More Energy Efficient World*. NREL Building Research teams are supporting DOE's retrofit focus for homes and commercial buildings through development of energy analysis tools, key performance data, and strong partnerships.

Modeling potential retrofit solutions helps identify the most efficient options. Optimization software applies a systematic approach to determine the most cost-effective, energy-saving strategies. NREL's optimization software automatically runs thousands of energy modeling simulations and evaluates interactions of a building's components. This results in a set of solutions to achieve optimal energy performance. The Building

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Research Support Facility *from page 1*

integration and innovative technologies, and participating in all design and construction review meetings to ensure the energy goals would be met. Seemingly small measures—such as using reflective paint to enhance daylighting or favoring laptops over PC workstations—added to the overall energy savings.

"The RSF is the culmination of our experience in designing cutting-edge, energy-efficient buildings. All of its energy-related systems—form, orientation, envelope, facade, daylighting, and mechanical systems—have been optimized to cost-effectively minimize energy consumption, which also makes it highly replicable in other projects," Judkoff said.

Because the number of projected RSF employees has grown from 650 to 822, and the building is now supporting the full campus data center, researchers adjusted the energy-efficiency standard to 35 kBtu/sf/year. As workers move in to the sparkling structure, NREL building energy experts will monitor all of the energy functions. But the lessons won't stop on the South Table Mountain campus in Colorado. The same group that helped the design-build team find the most economical way to reach ultra efficiency, that analyzed power loads, interfaced with staff and set operational goals, will continue to spread their findings. The project now stands as a working example that can inform future commercial building projects. The team's work isn't over yet. "We can't claim victory until we have monitored the energy performance for at least one year," cautioned Torcellini, NREL's Group Manager for Commercial Buildings. "We also intend to study the interplay between the occupants and the building's energy systems." ■

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>
> **Ron Judkoff,**
> Manager, NREL Buildings Research Program

Retrofits *from page 1*

Energy Optimization (BEopt) tool targets residential building efficiency and Opt-E-Plus is a commercial building application. In addition, NREL is developing testing methodologies to assess the accuracy of other residential and commercial energy analysis tools on the market.

NREL researchers make critical building data and metrics available to the public that not only improve the results of the retrofit efforts, but also provide a standardized way to evaluate performance.

NREL's national database of residential building retrofit measures helps users determine the most cost-effective means of improving energy efficiency in existing homes. The database provides consistent performance and cost data for energy analysis software tools such as NREL's BEopt.

NREL also developed commercial reference buildings for a variety of existing building types and climate zones, providing a consistent baseline to engineers and designers evaluating retrofit measures. Because the reference buildings can be used by EnergyPlus, DOE's most detailed energy simulation program, they also simplify the modeling process. Additionally, NREL developed a benchmark model for DOE's Building America residential research program—a standard against which to measure energy savings.

By creating alliances with industry, research teams, trade associations, and utilities, NREL puts its research results into practice throughout the marketplace.

As the technical lead for Building America, NREL manages and supports the external research teams working to achieve energy-saving targets of up to 50% in existing homes. Partnering with the Sacramento Municipal Utility District, NREL provides design, analysis, and field-monitoring support to residential retrofit demonstration projects that determine cost-effective strategies to reduce energy use by up to 50%.

Adding insulation to an attic is an effective way to reduce a building's energy use and improve occupant comfort.

NREL also actively supports DOE's Commercial Building Energy Alliances and Commercial Building Partnerships. NREL provides technical expertise to companies such as Best Buy, Kohl's, SUPERVALU, Target, Whole Foods, and CB Richard Ellis (CBRE)—all working toward 30% energy savings in existing buildings and 50% savings in new buildings. Currently, NREL and many retailers are developing prototypical retrofit stores with solutions that can be replicated. What's more, NREL and CBRE are retrofitting a 1980's skyscraper with a potential energy savings of 36% using cost-effective measures. "These practical applications educate the industry and inform NREL's research," said Ron Judkoff, manager of NREL's Buildings Research program.

Learn more about the research and deployment activities of NREL's commercial and residential building teams at *www.nrel.gov/buildings/capabilities.html*. ■

NREL Leads the Leaders in Advanced Biofuels Production Technologies

Creating new transportation fuels may be challenging, but creating a new transportation infrastructure would be extremely costly and difficult.

That's why the NREL-led National Advanced Biofuels Consortium (NABC) is developing technology to produce advanced biofuels—biomass-based hydrocarbon fuels that are compatible with existing gasoline, diesel, and jet engines as well as refineries and fueling stations.

The NABC, co-led by NREL and the Pacific Northwest National Laboratory, is a collaboration among 17 industry, university, and DOE national laboratory partners. In late 2009, DOE awarded $35 million in American Recovery and Reinvestment Act funds to the consortium which is operating with an additional $12.5 million in partner funds.

Developing Biofuels Production Technologies

The consortium is working to develop at least one, and up to three, biofuels production technologies to a pilot-plant-ready state in three years, when the award period ends. "To take a production process from concept to pilot-ready in three years is a huge challenge," said Consortium Director Thomas Foust. But the NABC is not starting from scratch. "We identified the leaders in the advanced biofuels field representing the necessary expertise in catalysis, synthesis, and refining. Those are the industry and university leaders we asked to join the consortium."

The NABC will spend one year investigating six biofuels conversion process options: fermentation, catalytic conversion, catalytic fast pyrolysis, hydropyrolysis, hydrothermal liquefaction, and one-step syngas-to-distillates. After one year, the NABC will determine which technology or technologies are most likely to be scalable to pilot-plant production. NABC partners will then concentrate their R&D efforts on those technologies.

In addition, NABC will investigate three proposed insertion points for advanced biofuels in a petroleum refinery. Biomass can be converted to bio-crude that can be co-processed with conventional crude oil, it can be upgraded into refinery-ready intermediates that are compatible with refinery streams that will undergo further processing, or it can be upgraded to a near-finished fuel or blendstock that will be minimally processed at the refinery.

> "NREL has long been known as the leader in cellulosic ethanol research. As that comes closer to commercial viability, NREL will be able to turn our research capability to advanced biofuels."
>
> Thomas Foust, Director NABC

NREL as a National Leader

The NABC award and resulting research establish NREL as the national leader in biofuels, according to Foust. And NREL is positioned to continue development of advanced biofuels after the consortium work is complete. "NREL is constructing an Integrated Biorefinery Research Facility and is upgrading its Thermochemical Users Facility—both contain pilot plants—with the development of advanced biofuels in mind," he said. "The NABC work aligns nicely with the vision for NREL's Biofuels Program. NREL has long been known as the leader in cellulosic ethanol research. As that comes closer to commercial viability, NREL will be able to turn our research capability to advanced biofuels." ■

Adam Bratis Speaks Out on "Science Friday"

On April 30, 2010, NREL's Biofuels Program Manager Adam Bratis was a featured speaker on National Public Radio's "Science Friday."

Bratis spoke with host Ira Flatow, other distinguished panelists, and audience callers about the potential of fuels derived from cellulosic ethanol and algae to meet the federal renewable fuel standard. The renewable fuel standard calls for using 36 billion gallons of biofuels in transportation fuel by 2022.

To download the podcast, visit the "Science Friday" Web site at *http://www.sciencefriday.com/program/archives/201004305*. ■

Testing Biodiesel in Emissions Control Devices

NREL engineers are testing biodiesel to see if the renewable fuel compromises the abilities of diesel particulate filters (DPF) and selective catalytic reduction (SCR) systems to reduce particulate matter and nitrous oxide emissions. This work is highly visible to the engine and catalyst industries, according to NREL engineer Aaron Williams. They are watching to see if biodiesel can become a more widely used fuel.

The research is key because biodiesel can contain trace metals that end up as ash in the exhaust, which can stick to emissions control equipment, thereby reducing the catalysts' effectiveness. At the current allowable limits set by ASTM International, potentially harmful amounts of metals could accumulate over the lifetime of the catalyst.

To measure the long-term effects of this residue, NREL engineers are burning biodiesel in an engine hooked up to SCR and DPF systems for the required equipment lifetime of 435,000 miles. The results of this work will either demonstrate that biodiesel metals are not an issue in DPF and SCR equipped engines, or will show that the current limit for these metals needs to be lowered to an acceptable standard. ■

NREL Partner Demonstrates Potential for High-Volume Solar Cell Manufacturing Using Semiconductor Industry Equipment and Know-How

RF Micro Devices (RFMD), as part of its cooperative research and development agreement (CRADA) with NREL, has successfully manufactured a photovoltaic (PV) cell using its high-volume six-inch gallium arsenide (GaAs) machinery. The cell was manufactured in RFMD's existing wafer-fabrication facilities (fabs) in Greensboro, North Carolina, with no fabrication equipment modifications.

The CRADA between NREL and RFMD began a little more than a year ago (see story, pg. 3, *Energy Innovations*, fall 2009). It combines NREL's ultrahigh-efficiency inverted metamorphic multijunction (IMM) solar cell technology and RFMD's high-volume semiconductor manufacturing facilities with the goal of reducing costs by dramatically increasing the scale of manufacturing PV cells. RFMD is already a global leader in the design and manufacture of high-performance compound semiconductor technologies for cell phones and other wireless communications systems. The involvement of this manufacturing giant could cause a significant shift in the PV manufacturing industry, especially in concentrating PV devices where cells such as the IMM are typically used.

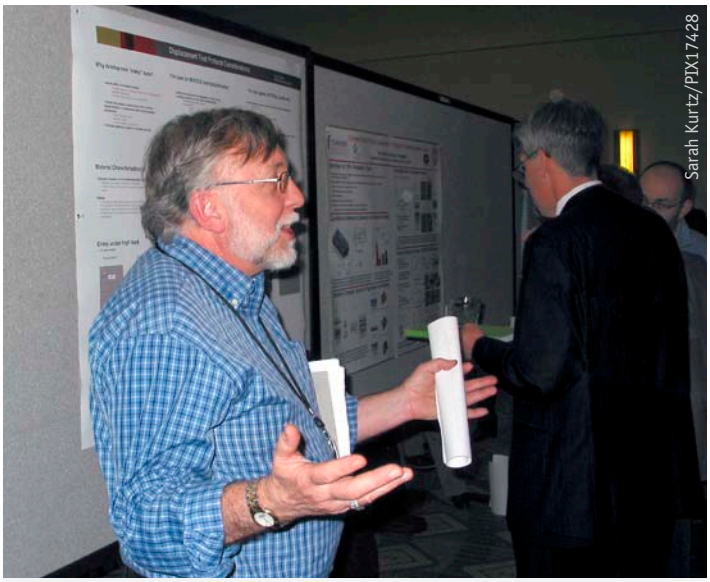
Successful manufacture of the GaAs cell is a critical milestone in the multiyear, multiphase CRADA, the ultimate goal of which is to produce an IMM cell. Manufacture of the GaAs cell proves that a working solar cell can be made using RFMD's existing high-volume fabs.

NREL has contributed considerable technical expertise to the CRADA. Principal Scientist Mark Wanlass, inventor of the IMM cell, is also the NREL principal investigator for the CRADA. He and his team have worked with RFMD on crystal growth, defining the structure and fabrication of the IMM device and evaluating its performance. NREL has also provided reference solar cells for measurements, testing expertise and facilities, and assistance to RFMD in defining specifications to create its own testing capabilities. ■

Reliability Workshop Brings the PV Community to Golden

February 18–19, 2010, Golden, Colorado

February saw a rush of photovoltaic (PV) community members come to NREL for the PV Module Reliability Workshop. NREL is ideally suited to host such a meeting based on its broadly recognized leadership in all phases of PV R&D, including world-class PV reliability experts and testing facilities. Participants toured those facilities during the workshop.



DuPont's Sam Samuels presented a poster about the measured "creep" of some new materials that may improve the cost and performance of PV modules but may also soften and move or "creep" when heated. Sam won an award for "best insightful conversation at a poster" at the PV Reliability Workshop.

Sarah Kurtz, manager of the Technology Applications & Reliability Group within the National Center for Photovoltaics, organized the workshop for DOE's Solar Energy Technologies Program. She had input from several colleagues at NREL and from PV specialists from Amonix, Atlas, BP Solar, Colorado State University, Dow, DuPont, Emcore, General Plasma, SolFocus, and Spectrolab.

Kurtz sees the need for PV reliability research as crucial and straightforward. "PV products that generate electricity for decades without significant reduction in performance provide a better return on investment than similarly priced, but less reliable, products," she says. "However, identifying whether a product works well when it's new and first deployed in the field is much easier than predicting its performance decades into the future."

The workshop organizers solicited input from the PV community about issues important to them, and many of those issues found a place on the agenda. They also encouraged sharing of information about issues common to all—such as how modules fail and how to test for these failures—while accepting the companies' needs to withhold certain information to maintain their competitive advantage.

Each company presented either an oral or poster presentation. Although many of the companies initially responded that presenting information would not be possible, most were creative and identified something interesting that their management approved for presentation. In the end, more than 50 companies participated and all but two obtained approvals and presented their work. The workshop presentations are available online at *www.eere.energy.gov/solar/pv_module_reliability_workshop_2010.html*. ■

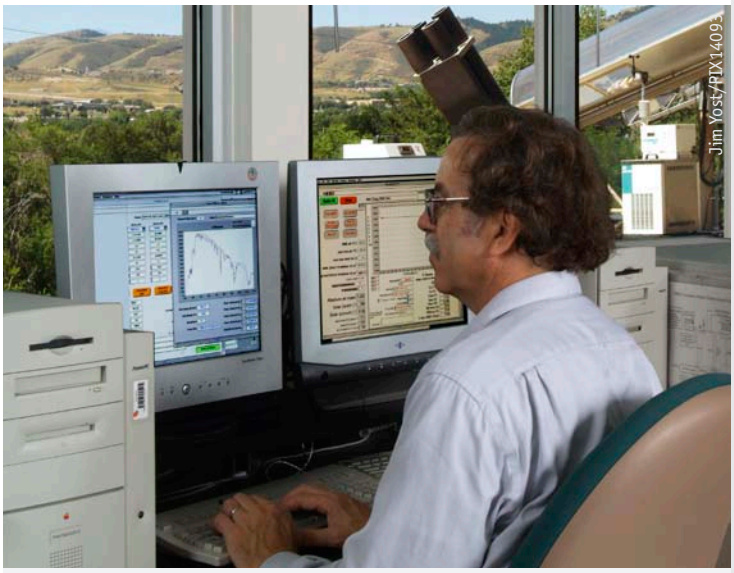
Keith Emery Epitomizes High Standards of Photovoltaics

During his 30-year NREL career, Keith Emery has become a pillar of the international photovoltaic (PV) community, according to Ryne Raffaelle, National Center for Photovoltaics (NCPV) director.

Emery, a principal research supervisor who leads the Cell and Module Performance team within the NCPV's Measurements and Characterization group, recently earned NREL's H.M. Hubbard Award for sustained, high-level research contributions and leadership in furthering the laboratory's reputation. Emery has pioneered much of the science required to measure the performance of all PV technologies, from the conventional to the complex. His work spans multijunction concentrators to next-generation devices such as organic, dye-sensitized, and quantum-dot-based PV.

Raffaelle emphasizes the difficulty of Emery's task. "Solar cell performance depends on a myriad of factors," he says. "And with the rate that the PV industry has grown and diversified, the stakes have become extraordinarily high. The measurements that Keith performs have enormous consequences for the industry. The fact that he has advanced the theory and art of PV measurements is the reason that the industry as a whole demands the NREL stamp of approval."

Emery also plays a crucial role as the conscience of the PV community. In 2009, Emery joined colleagues in writing an editorial published in *Materials Today*, a leading scientific journal, calling for clear standards of practice. "This editorial brought into very clear focus that there are certain standards of practice that were not being maintained within this rapidly expanding community," Raffaelle says."This article sent shock waves throughout the entire PV world. It was an example of extraordinary leadership on Keith's part." ■


Jim Yost/PIX14093

Principal Research Supervisor Keith Emery has led the development of much of the science required to measure the performance of all PV technologies during the past 30 years.

John Benner to Manage CRSP


Rommel Noufi/PIX17431

John Benner at the Solar Energy Research Facility (SERF).

John Benner is the manager of the PV Industry Partnerships Group in the National Center for Photovoltaics at NREL. In January, he assumed an additional role as managing director of the Center for Revolutionary Solar Photoconversion (CRSP). CRSP is a research center of the Colorado Renewable Energy Collaboratory, a partnership between NREL and Colorado's premier research universities: the University of Colorado at Boulder, Colorado State University, and Colorado School of Mines. Benner is a "career solar professional." He brings more than 30 years of PV experience to CRSP's mission of creating new and marketable solar-based technologies by performing cutting-edge basic and applied research. In February, CRSP announced awards totaling $800,000 for ten advanced solar research projects. Funding for this program comes from CRSP corporate members and matching funds from the Collaboratory via the State of Colorado. For more information about the Collaboratory and CRSP: *www.coloradocollaboratory.org/* ■

NREL's Dr. David Renné elected President of ISES

Dr. David Renné, principal program manager with NREL's Resource Information and Forecasting Group, was elected president of the International Solar Energy Society (ISES) in December 2009 for a term that runs from January 2010 to December 2011.

He has managed solar and wind energy resource assessments and the development of geographical information system tools for a number of countries in Asia and South Asia, Central America, South America, and Africa. Much of Renné's recent work at NREL has been for international organizations such as the U.S. Agency for International Development, the United Nations Environment Program, the United Nations Development Program, the United Nations Department of Economic and Social Affairs, and the International Renewable Energy Agency.

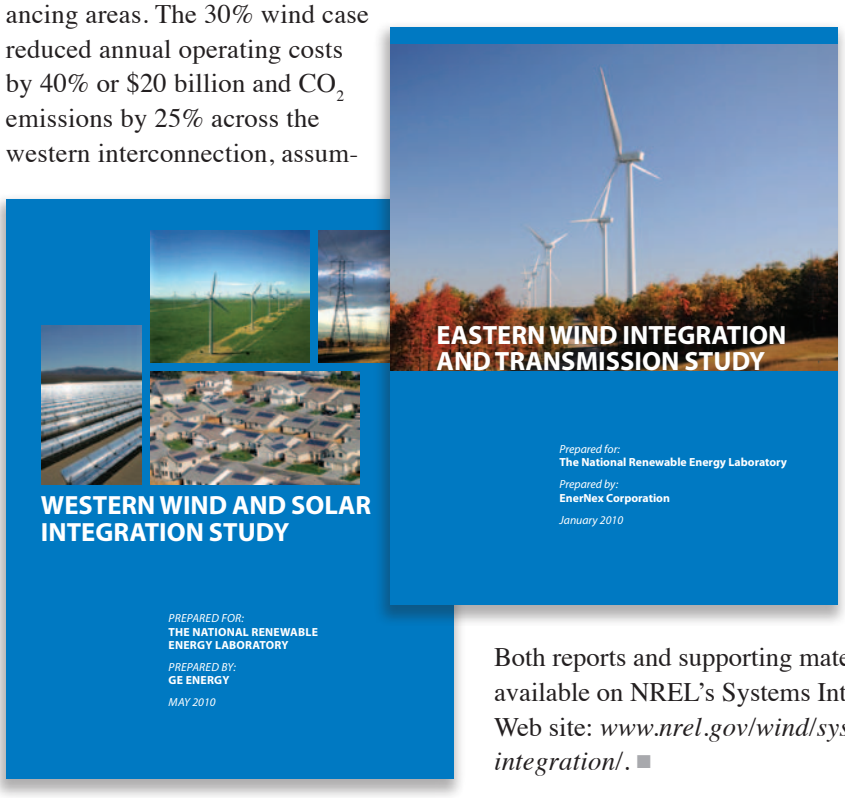
"It's a lot of travel, though my international role connects NREL to a vast network of researchers and practitioners around the world in the area of renewable energy R&D and deployment of solar technologies," says Renné. ■

NREL Publishes Largest U.S. Wind Integration Studies Ever Undertaken

NREL has led an effort to assess the operational impacts of integrating larger amounts of wind and solar energy into grid operators' energy portfolios. In the first half of 2010, NREL published two major wind integration transmission studies: the *Eastern Wind Integration and Transmission Study* and the *Western Wind and Solar Integration Study*. Both studies examine the potential for wind energy to supply 20%–30% of the nation's electricity by the year 2030 as envisioned in the 2008 DOE report *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*. The release comes against the backdrop of 2009, when the U. S. wind power industry installed more wind generation capacity—10,000 megawatts—than in any previous year.

The *Eastern Wind Interconnection Study* evaluates the future operational and integration impacts of up to 30% wind energy penetration into the power system in the study year 2024. The study encompasses the majority of the utilities in the Eastern Interconnection. It includes a high-level analysis of transmission needed to deliver the wind energy to load centers and a cursory analysis of carbon pricing impacts. Results from the study show that there are no fundamental technical barriers to the integration of 20% wind energy into the electrical system; however, transmission planning, system operation policy, and market development need to continue to evolve for these penetration levels to be achieved. The study also found that costs for integrating large amounts of wind generation are manageable with large regional operating pools because increasing the geographic diversity of wind projects in a given operating pool generally makes the aggregated wind power output more predictable and less variable.

The *Western Wind and Solar Integration Study* examines the operational impact of up to 30% wind and 5% solar energy penetration on the WestConnect grid in Arizona, Colorado, Nevada, New Mexico, and Wyoming. The study concluded that 35% wind and solar energy penetration in WestConnect is feasible, provided that there is sub-hourly scheduling and substantial cooperation between utility balancing areas. The 30% wind case reduced annual operating costs by 40% or $20 billion and CO_2 emissions by 25% across the western interconnection, assuming $9.50/ MBTU gas. At a $3.50/MBTU gas price, operating costs were reduced by 25% and CO_2 by 45%.



Both reports and supporting materials are available on NREL's Systems Integration Web site: *www.nrel.gov/wind/systems integration/*. ■

NREL's Solar Advisor Model Used in Study

Analysts for the Western Wind and Solar Integration Study (WWSIS) used NREL's Solar Advisor Model (SAM)—a software program that uses various inputs to produce a variety of outputs—to examine solar energy potential in the Western United States (see main story this page). This NREL-developed tool was key in evaluating the technology's contributions to reliability and capacity in the region.

SAM, which looks at solar power systems from all angles, can be used to evaluate the levelized cost of energy (LCOE). It combines detailed performance modeling, cost data, and financial models within a user-friendly interface for most solar technologies.

For the WWSIS, SAM's computer scripting language allowed it to be quickly run over hundreds of weather locations to provide a wealth of data to the study participants. This information was then combined with modeled wind production data to do the study.

The solar technologies represented in SAM include concentrating solar power (CSP) parabolic trough, dish-Stirling, and power tower systems, as well as flat plate and concentrating photovoltaic technologies. SAM incorporates the best available models for analyzing the impact of changes to the physical system on the overall economics (including the LCOE). But, most important, it promotes the use of a consistent methodology for analysis across all solar technologies, including financing and cost assumptions.

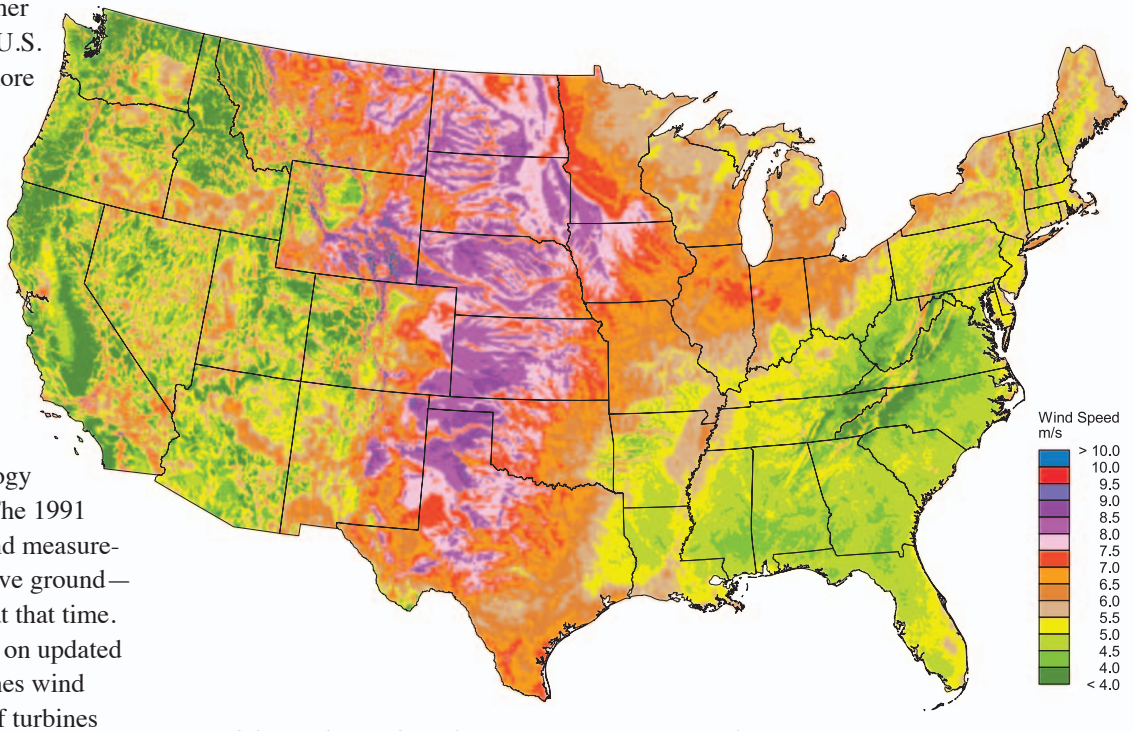
More than 5,000 users have downloaded the version released in March 2010, which is available at *https://www.nrel.gov/analysis/sam/*. ■

NREL and AWS Truepower Release New Wind Resource Assessment at 80 to 100 Meters for the Contiguous United States

According to a new wind resource assessment released by NREL and AWS Truepower in February 2010, wind power has the potential to produce about 37 million gigawatt-hours (GWh) of electricity per year (not adjusted for losses that are typically about 15%). That's more than three times the potential shown in a previous assessment published by the Pacific Northwest National Laboratory in 1991. Last year the total electricity generation from *all* sources was about 4 million GWh. And although 2009 was another record-breaking year for the U.S. wind energy industry, with more than 10,000 megawatts of new capacity installed, wind energy still only accounts for about 2% of our nation's energy portfolio.

Why has wind energy potential increased so dramatically over that last two decades? Have the blowing winds increased that much? No, but wind energy technology has advanced considerably. The 1991 assessment was based on wind measurements taken at 50 meters above ground—the tower height of turbines at that time. The new assessment is based on updated computer models and examines wind potential at the hub heights of turbines being built today—between 80 meters and 100 meters. These larger, more advanced machines operate on taller towers and capture the faster winds found at higher elevations. They're also much more efficient at producing wind power.

In addition to greater hub heights, the new assessment is based on wind turbine capacity factors of 30% and greater that are generally considered suitable for development with today's wind power plants. The capacity factor is the amount of power produced per year divided by the amount of power that would be produced if the wind turbine operated at full capacity all the time. The study found that at an 80-meter hub height these areas with about 10,500 gigawatts (GW) of wind capacity could potentially generate approximately 37 million GWh of electricity per year. The NREL study also found that at an 80-meter hub height with a capacity factor of 40% and greater in areas with about 5,500 GW of wind capacity, the generating potential is almost 22 million GWh per year. And at a 100-meter hub height with at least a 30% capacity factor, in areas with about 12,000 GW of wind capacity, the generating potential is almost 45 million GWh per year. That's about 20% more than at the 80-meter hub height. As a result of these new figures, Indiana, Ohio, and Oregon moved onto the list of the top 20 windiest states for the first time. In addition to the wind potential estimates, as part of its collaborative effort with AWS Truepower, NREL produced maps of the annual average wind speed at 80-meter height for the contiguous United States and for each state. See the wind maps and the table of results on the Wind Powering America Web site: *www.windpoweringamerica.gov/wind_maps.asp*. ■



One of the wind maps from the NREL/AWS Truepower wind resource assessment.

NREL Researchers Receive 2010 Annual Achievement Award

NREL's Brian Parsons, Dave Corbus, and Debbie Lew received the Utility Wind Interest Group's (UWIG) 2010 Annual Achievement Award at the UWIG 2010 Spring Technical Workshop held April 15–16 in Portland, Oregon. The award recognized the NREL team, along with team members for EnerNex and GE Energy, for their role in the Eastern Wind Integration and Transmission Study (EWITS) and the Western Wind and Solar Integration Study (WWSIS). (See story on pg. 6.)

The award for Parsons notes his "sustained leadership in development and management of a national wind integration program in support of electric utility requirements." The awards for Corbus, Lew, and EWITS and WWSIS team members highlighted the studies' roles in breaking new ground in the largest and most comprehensive analyses of transmission planning and wind integration in the Eastern and Western Interconnections. ■

Breaking Ground on a New Wind Turbine Test Facility

To keep up with the wind power industry's need to test larger blades, DOE, NREL, and the Massachusetts Clean Energy Center (MassCEC) broke ground in late 2009 for the construction of a new blade test facility in Boston. When it opens in 2011, this will be the only U.S. facility capable of testing wind turbine blades up to 90 meters long. The new facility is critical because NREL's National Wind Technology Center (NWTC) currently operates the sole facility in North America capable of performing full-scale testing of large wind turbine blades, but the NWTC can only test blades up to 50 meters long.

The blades of the most commonly installed wind turbine today (1.5-MW) are 35 to 40 meters long. Several manufacturers are now developing 3-MW to 10-MW wind turbines with blades that stretch to between 50 and 90 meters in length. And many of these machines will be installed in harsh off-shore environments.

As conventionally designed and manufactured blades have gotten longer, their increased weight has tended to outweigh their ability to capture more energy, so manufacturers are exploring new designs and materials for longer blades that will increase the performance and reduce costs. Before the new blades are deployed in the field, the designs and materials need to be tested and validated for strength and performance.

The substantial substructure for the new facility is now complete. When the facility is fully completed, it will provide the capability for industry to spur the development of next-generation wind turbine technology. ■

New "Red Mesa" Computing Power Focuses on Recalcitrant Cellulose and More

Red Mesa is a new high-performance computing (HPC) system that helps bridge the gap between NREL's present HPC facilities and capabilities and the new Energy Systems Integration Facility to be completed in late 2012. Red Mesa is the fastest HPC system in the world dedicated to advancing energy efficiency and renewable energy technologies. It will help tackle our nation's energy challenges in ways that are not possible through traditional experimentation alone. It was acquired as part of a collaboration between NREL and Sandia National Laboratories and is located in Albuquerque, New Mexico. NREL researchers recently used simulations on Red Mesa to measure the intrinsic toughness of the

NREL Tools Help Industry Partners Improve Parabolic Troughs

Researchers in NREL's Thermal Systems Group are improving existing tools and developing new ones that allow industry partners to evaluate the optical performance of concentrating solar power (CSP) collectors.

NREL's support of testing pre-commercial systems is helping the CSP industry identify shortcomings of intermediate designs that can be corrected during the design cycle. And testing of commercial designs also gives equity and debt investors additional confidence that the collector design will work as specified by the provider.

One powerful evaluation tool developed by NREL is the Video Scanning Hartmann Optical Test (VSHOT), which characterizes the optical performance of both point-focus and line-focus collectors. This test has been the gold standard used by Acciona, SkyFuel, Abengoa, and Alcoa to determine the optical quality of collectors and identify areas for improvement. VSHOT, which can be used both in laboratory and field settings, works by combining laser ray tracing with fast video imaging to mathematically describe the mirror concentrator surface and determine the deviation from the desired surface.

In developing SkyTrough—a new, commercial parabolic trough collector—SkyFuel used results from VSHOT to guide significant design improvements that helped garner an R&D 100 Award in 2009 from *R&D Magazine*, which NREL shared with SkyFuel.

Allison Gray uses the VSHOT set-up to measure the optical efficiency of a trough collector.

Optical efficiency in a parabolic trough CSP system is the percentage of incoming light coming directly from the sun that is absorbed by the solar collector's receiver tube. This measure is a critical characterization of optical performance because it is directly proportional to the energy delivered by the field of solar collectors to the CSP plant's power cycle. Hence, improving the optical efficiency by 5%, with no increase in capital cost, can essentially lower the cost of delivered electricity by the same 5%. Results from a Solar Advisor Model analysis (see story pg. 6) have shown that a 20% improvement in optical performance from initial prototype to final design—can drop the levelized cost of energy. This is a significant boost to reaching the energy cost targets for electricity generated by CSP power plants.

Performing VSHOT tests is time-consuming, and NREL cannot meet all the demands for new testing by industry. Therefore, researchers are coming up with ways to increase the speed of VSHOT testing. In addition, they are working on other optical techniques, such as deflectometry and a Distant Observer method, that have the potential to gather data more rapidly. ■

plant cell wall, or biomass recalcitrance, at the molecular level for the first time. This computationally intensive simulation used 1.75 million processor hours and was completed in roughly 6 weeks—something that would have taken up to 6 months on a conventional supercomputer. The thermodynamic results will aid in developing quantitative, mechanistic models for biomass deconstruction by natural and engineered enzyme systems, which are an essential component of biofuels manufacturing.

In addition to the cellulosic ethanol work, NREL is currently testing and validating a variety of simulation codes that will soon be running on the Red Mesa system. Example application areas include:

- Analyzing the complex processes and chemistries for efficient thermochemical biofuels production
- Designing novel materials having the exact properties required for game-changing advancements in solar cell performance and identifying novel materials with radically improved thermal energy storage and stability characteristics for low-cost, highly efficient concentrated solar power systems
- Modeling multi-turbine arrays for increased wind plant performance, improved gearbox reliability and energy capture potential, and more accurate coupled energy forecasts
- Determining optimal cost and energy performance solution sets for energy efficient building retrofits and for new ultra-efficient buildings
- Numerical simulation of unique nanomaterials for marked improvements in fuel cell performance and thermal management. ■

A Big Boost for NREL's Battery Testing

NREL is using $2 million in American Recovery and Reinvestment Act funding (awarded by DOE in November 2009) to expand the Battery Thermal and Life Test Facility. The investment will upgrade and enhance energy storage laboratory testing and analysis capabilities, which include customized calorimeters and innovative computer simulation models.

Hybrid, plug-in hybrid, and all-electric vehicles (EVs) reduce petroleum consumption, but their batteries can be expensive. So, DOE supports advanced energy storage R&D to lower battery (and overall vehicle) costs and improve performance.

"DOE recognized that the national labs' need to be equipped to test the new batteries that industry will be producing with ARRA funds," says Ahmad Pesaran, Principle Engineer and Energy Storage Task Leader.

NREL is acquiring up to 20 new battery testers, to nearly triple the lab's testing capability. Two new calorimeters will measure the heat and efficiency of small and medium-sized cells and augment the two large calorimeters in the lab. Those customized calorimeters measure a battery's or ultracapacitor's heat generation at various rates, temperatures, states of charge, and heat capacities.


Pat Corkery/PIX16954

NREL Engineer Dirk Long holds a liquid-cooled battery module consisting of 12 cylindrical lithium ion cells. The unit was tested for Saft America as part of a DOE project.

Industry partners then use the data to improve battery designs. The data will also be used to validate NREL's computer models of thermal and electrochemical battery performance. Modeling and simulating advanced energy storage systems helps industry create innovative designs that enhance overall vehicle performance. ■

New Transportable Molecular Beam Mass Spectrometer Provides On-Site Analysis of Thermochemical Biofuels Processes

NREL and TDA Research in Wheat Ridge, Colorado, have designed and built a new transportable molecular beam mass spectrometer (MBMS) for use by industry partners to analyze samples along their thermochemical process lines. The MBMS provides rapid, real time, comprehensive analysis for a precise inventory of the gases, tars, and other chemical compounds generated during biomass gasification and pyrolysis processes.

> "The real benefit is direct sampling from high-temperature systems."
>
> Daniel Carpenter, NREL Scientist

"The real benefit is direct sampling from high-temperature systems," says NREL scientist Daniel Carpenter. Most commercial analytical equipment requires samples that are conditioned in ways that can alter the sample. In contrast, the MBMS takes the whole sample at reaction temperature, freezes the chemistry, and measures the products as they are produced, making it ideal for hooking up to a pilot-plant process.

NREL's MBMS, which can be operated remotely from a control room, has automated sample handling and onboard calibration capabilities for quantitative results.

Because plant owners may only need to use the instrument during initial plant start-up or process development, NREL provides on-site operation of the MBMS, including analyzing and interpreting the mass spectra. Next year NREL will take the MBMS to two DOE integrated biorefinery projects: a ClearFuels gasification plant in Commerce City, Colorado, and a Renewable Energy Institute International pyrolysis plant in Toledo, Ohio. ■

NREL Software Helps Industry Cut Energy Use in Trucks

CoolCalc, a new modeling tool developed by NREL engineers, simulates energy use for climate control in long-haul truck cabs and assesses the impact of various energy-saving technologies. CoolCalc leverages DOE's EnergyPlus and OpenStudio building energy simulation tools developed by engineers in NREL's Buildings Research Program.

For air conditioning or heating during mandated rest periods, sleeper trucks idle an average of about 1,830 hours per year, consuming a whopping 838 million gallons of fuel nationwide—presenting a great opportunity for energy saving. Earlier this year, NREL outfitted truck cabs from two major manufacturers with instrumentation to measure temperature and humidity. Results will be used to validate CoolCalc.

"Engineers can use CoolCalc to analyze the impact of various energy-saving technologies that can help truckers stay comfortable with minimal engine idling," NREL engineer Jason Lustbader said. Some near-term energy-saving technologies include improved insulation, ventilation, window glass, and window coverings. CoolCalc enables users to assess these and more high-risk design options to determine their potential impacts over a range of use scenarios and weather conditions.

With funding from DOE, NREL is helping the trucking industry design trucks that use less fuel and reduce operating costs. ■

High Throughput Platform Brings Fast, Low-cost Biomass Analysis to NREL

Unlocking the biochemical secrets of plant cell walls used to take a laboratory of analysts more than a week to complete—for a handful of samples. Now, with an automated, high throughput (HTP) reactor system, or pipeline, NREL researchers can screen almost 2,000 samples at once.

Recalcitrance (the degree to which biomass resists being broken down into sugars) is a complex property. To understand it, large numbers of samples must be analyzed under identical conditions. NREL has excellent capabilities for measuring biomass feedstock characteristics, but the process is labor-intensive and time consuming. No equipment existed for rapid, high-throughput screening of biomass recalcitrance, so NREL scientists decided to design their own.

NREL's parallel reactor system, custom-designed at NREL with help from University of California-Riverside scientists is the first truly high throughput pretreatment and enzyme digestion system for biomass conversion research. Scientists found that a successful HTP system required a sample vessel that would integrate with standard laboratory automation equipment while withstanding the extreme temperature and pH conditions of biomass conversion, and to then perform the pretreatment, enzyme hydrolysis, and sugar assay steps all within the same vessel.

The NREL researchers designed a 96-well stackable reactor plate with steam channels so that 20 plates could be processed in each

NREL Develops New Financial Analysis Tool for Fuel Cell Power Systems

NREL recently launched the Fuel Cell Power Model, a new financial software tool for analyzing fuel cell-based tri-generation (combined heat, hydrogen, and power) systems. The model helps users determine the cost of energy from these systems, which are suitable for large facilities.

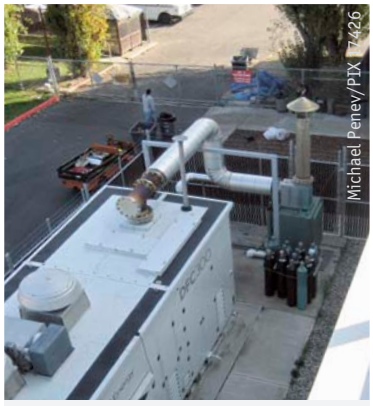
The model comes in two versions—one for molten carbonate fuel cell systems and another for phosphoric acid fuel cell systems. These big fuel cell systems have high operating temperatures, so they produce useful heat in addition to electricity.

"Electricity can be generated more efficiently by the fuel cell than by conventional power technologies," says NREL analyst Darlene Steward, who helped develop the tool. "And using the waste heat from the fuel cell for space and water heating makes these systems even more efficient."

Some excess heat from tri-generation can also be used to produce hydrogen for vehicle fuel or to convert to electricity.

These systems are important in emerging fuel cell markets because they lower hydrogen production costs, enable on-site hydrogen production, reduce electricity transmission congestion, and provide backup power.

"Tri-generation systems hold great promise for grid-congested areas that need additional power," Steward added. "And the financial incentives available today make these systems even more attractive."



This molten carbonate fuel cell system provides electricity and heat for a postal processing facility in San Francisco.

The model includes calculations for several federal tax credits and allows users to input other tax credit calculations as well. It determines the greenhouse gas emissions benefits compared to conventional power technologies. And users have the option of importing energy-demand profiles for various types of buildings as well as renewable-energy-supply profiles for cities in eight climate zones across the nation.

"Nearly 100 people from industry, academia, and government have downloaded the model so far," Steward said. ■

NREL senior scientist Steve Decker watches a robot dispensing samples of powdered biomass into a reactor plate, part of NREL's high-throughput biomass recalcitrance pipeline.

run, pretreating 1,920 biomass samples simultaneously, quickly, and at uniform temperatures. To implement the basic design, researchers adapted solid and liquid-dispensing robots to distribute biomass into the parallel plate reactors and add precise amounts of pretreatment catalyst. After pretreatment, the same robotic dispenser adds enzymes directly into the wells and the plates are resealed. After 3 days of incubation, the products of enzyme degradation are primarily sugars. Scientists reduced the analysis to quantify the amount of glucose and xylose released by the enzymes to about 30 seconds per sample by adapting the technology used by diabetics to monitor blood sugar.

"Up until last year, no one had been able to integrate all the components of biomass recalcitrance analysis into a single high-throughput system," says NREL Senior Scientist Steve Decker, leading the effort. "Thermochemical pretreatment at this scale and throughput had only been dreamed of."

With the new HTP pipeline, NREL is generating data to help other scientists identify and develop the most promising biomass feedstocks for higher efficiency, lower cost biofuels conversion processes. So far, the pipeline has screened thousands of biomass samples, and the data is being carefully analyzed by research partners around the world. These results will be combined with genetic information gathered by researchers from DOE's BioEnergy Science Center and other partners.

"This work will ultimately lead to identifying genes that will lead to lower recalcitrance," says Mark Davis, a principal group manager in NREL's National Bioenergy Center.

> **"Up until last year, thermochemical pretreatment at this scale and throughput had only been dreamed of."**
>
> **Steve Decker,**
> NREL Senior Scientist

Findings from high throughput screening are not meant to replace precise compositional data, but rather they provide a quick, lower-cost way to compare large numbers of samples and identify which feedstocks stand out and should be further studied. In combination with NREL's more detailed compositional analysis data, this system promises to be a powerful tool. ■

NREL's Trudy Forsyth Recognized as One of Top 10 Women in Wind and Solar

NREL's Trudy Forsyth, one of the "Top Ten Women in Wind and Solar" at the National Wind Technology Center.

The *Green Economy Post* recently honored NREL's Trudy Forsyth as one of the "Top 10 Women in Wind and Solar." The *Post* recognized Trudy for her contributions to the evolution of small wind energy technology, her efforts to increase the deployment of small wind systems, and her determination to diversify the workforce by encouraging more women to pursue engineering degrees. In 2004, Trudy co-founded "Women of Wind Energy," a national organization devoted to attracting women to the wind power industry.

As a mechanical engineer at NREL for 16 years, Trudy has supported the advancement of small wind technologies. She has contributed to dozens of publications, from International Electrotechnical Commission (IEC) technical standards to the American Wind Energy Association (AWEA) Small Wind Turbine Industry Roadmap. Trudy currently leads NREL's Distributed Wind Energy projects, which covers small wind independent testing, midsize turbine development, and small wind regional test centers. Her efforts include development of new wind turbine components and technology, serving as NREL's liaison on the AWEA Small Wind Turbine Committee, and presenting small wind turbine technical, state policy, and market information to U.S. and international audiences.

As chair of the ASES Small Wind Technical Division, Trudy serves on the ASES board and is a board member of the Small Wind Certification Council. In addition, Trudy was recently selected to participate in revising the international small wind standard, 61400-2 and the International Energy Agency's Task 27, International Small Wind Labeling.

Trudy is a past NREL Staff Award winner for Outstanding Community and Professional Service, and she earned an Interstate Renewable Energy Council (IREC) Special Recognition Award in October 2005 for her leadership promoting the use of renewable energy. ■

NREL's Legacy: Decades of Advancing PV Research and Bolstering the Thin-Film PV Industry

Since the late 1970s, NREL (then SERI) has aggressively advanced PV technologies and fostered the PV industry. NREL holds several solar cell efficiency world records that have coincided with technological breakthroughs—not just incremental improvements—in all types of PV technologies. NREL's role in developing thin-film technologies has been particularly strong.

In the 70s, thin-film PV efficiencies ranged between 0% and 9%. NREL research has since enabled breakthroughs in solar cells using two kinds of technology: copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe) semiconductors. Currently, these technologies are 20% and 16.7% efficient, respectively. These breakthroughs have raised CIGS and CdTe technologies to a level where they are now competing with the more established crystalline-silicon semiconductor technologies.

Through collaborations with industry, NREL has helped deliver both types of thin-film technology to market. NREL uses industry partnerships such as those that allow the laboratory to collaborate with a company on a project while protecting intellectual property, and give the company the option of licensing any inventions that may arise. Currently, NREL has 19 industry partnerships with private businesses for CIGS and CdTe projects.

"Such mechanisms allow technology transfer to be done in a confidential and effective manner, so we can focus on solutions to roadblocks encountered by private companies in their efforts to commercialize their products," says Senior Scientist Miguel Contreras, leader of NREL's CIGS team.

One of NREL's many successful partners is Ascent Solar Technologies, Inc., of Thornton, Colorado. This manufacturer of thin-film CIGS PV modules on a flexible plastic substrate was selected in 2009 as an NREL PV Technology Incubator program partner and a recipient of Colorado Renewable Energy Collaboratory research funds. Ascent Solar's extremely lightweight and flexible technology produces the highest efficiency levels currently available on plastic. This module easily integrates into a variety of product applications, including roofing surfaces, portable electronics, defense applications, and commercial transportation.


Pat Corkery/PIX 15432

Aztlano Archuletta, a research technician, services the multi-chamber silicon cluster tool, which is used for research on thin-film solar cells. The tool is housed in the Process Development and Integration Laboratory in NREL's Science & Technology Facility.

NREL holds several solar cell efficiency world records that have coincided with technological breakthroughs—not just incremental improvements—in all types of PV technologies.

Abound Solar, which manufactures CdTe PV modules in Longmont, Colorado, is another company that has reaped the benefits of NREL's thin-film research. The company has taken technology developed with NREL support and combined it with a cutting-edge deposition process and other low-cost, rapid production methods. These give the manufacturer a huge competitive advantage. Abound Solar has signed long-term sales agreements with two German solar companies and has also received $12.6 million in Advanced Energy Manufacturing Tax Credits, which will offset the cost of investing in the additional manufacturing capacity.

Much of the success of these two companies can be attributed to their joint work with NREL and to NREL research. Such successes are replicated many times over through NREL's industrial partnerships, which help get renewable energy and energy efficient technologies to market quickly. ■

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