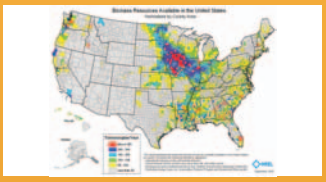
National Renewable Energy Laboratory
Innovation for Our Energy Future

Energy Innovations
Science & Technology at NREL

Winter 2010

In this issue, we highlight renewable fuels and vehicle systems.

NREL/EPA report estimates U.S. biomass resources



NREL dives again into water power research

Plug-in hybrids spark extensive NREL research

and more.

Published by the National Renewable Energy Laboratory

Sunlight Advances Hydrogen-Production Technology

Hydrogen offers great promise as a clean fuel in our nation's energy portfolio. And recent experiments by NREL senior scientist Heli Wang mark a significant step forward in hydrogen-production technology.

Abundant on Earth, hydrogen is almost always found in combination with other elements, such as with oxygen (in water) and carbon (in plant matter). To obtain pure hydrogen, it must be extracted from hydrogen-containing compounds.

> "This research represents a major step toward achieving DOE's hydrogen efficiency and durability goals ."
>
> **Heli Wang,**
> NREL researcher

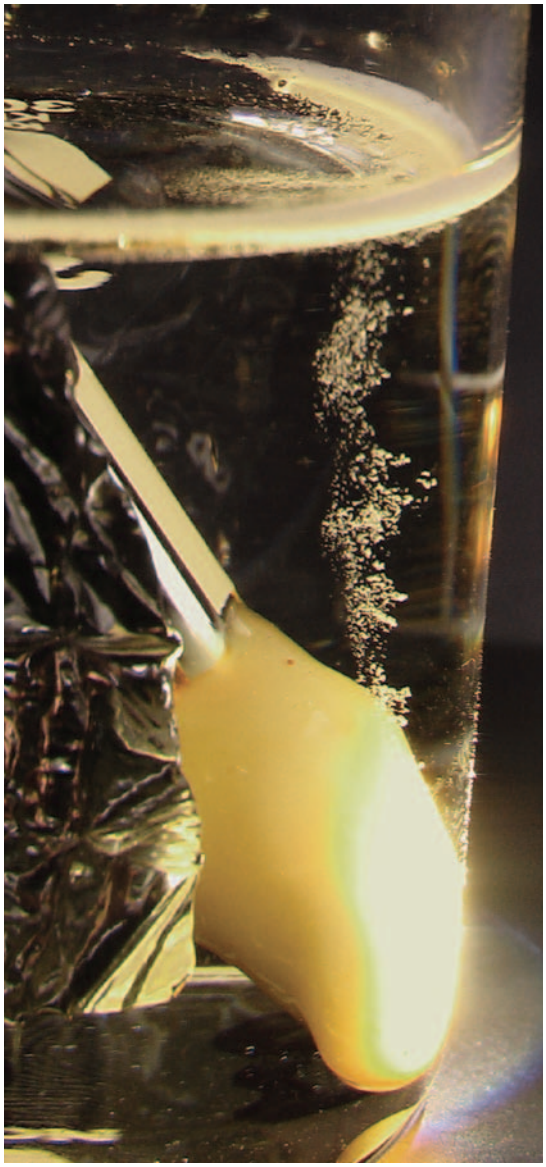
One of the cleanest ways to produce hydrogen is to use sunlight to split water molecules into hydrogen and oxygen. This is achieved with the solar-powered photoelectrochemical (PEC) process, which uses semiconductors immersed in an aqueous electrolyte (solution that conducts electricity).

The PEC process is promising, but currently no single semiconductor material can meet the U.S. Department of Energy (DOE) 2013 goals: 8% solar-to-hydrogen efficiency and 1,000-hour durability. Semiconductors made with metal oxides are stable, but not very efficient. Other highly efficient semicondutor materials are unstable in aqueous environments.

Wang's experiments build on decades of NREL research and collaboration to improve the durability of photovoltaic cells for PEC hydrogen production. In 1998, NREL's John Turner developed a record-breaking tandem photovoltaic cell (made of gallium-indium-phosphide/gallium-arsenide) with an impressive 12.4% solar-to-hydrogen efficiency. Unfortunately, the tandem cell demonstrated a functional lifespan of only about 24 hours. Since then, research has focused on identifying materials and systems that are durable, stable, and do not corrode in aqueous environments.

The original aqueous solution used in the tandem cell contained sulfuric acid. As an alternative electrolyte, Wang employed a nitrate solution in which the semiconductor suffered significantly less corrosion. In fact, one sample showed virtually no damage after a 24-hour test.

"This research represents a major step toward achieving DOE's efficiency and durability goals," Wang says. "To fully understand why the nitrate solution inhibited the corrosion of the semiconductor, future experimental and theoretical work will focus on identifying the inhibition mechanism. This will help us further extend the durability of the semiconductors." ■



Light shining on a photoelectrochemical cell immersed in water produces bubbles of hydrogen and oxygen. Photo credit: Todd Deutsch/PIX 16424.

Researchers Test Higher Blends of Ethanol in Fuels

Ethanol industry groups believe that gasoline blended with 15% or 20% ethanol (known as E15 or E20) will help meet the new U.S. renewable fuel standard. Authorized by the Energy Independence and Security Act of 2007, that standard calls for 36 billion gallons of renewable fuels to be blended into the fuel we use by 2022. But automakers and gas station owners have some concerns. What if the added ethanol causes fuel tanks and dispensers to corrode or creates engine problems?

This is where reliable research studies come in. With funding from DOE, researchers at NREL and Oak Ridge National Laboratory (ORNL) are providing important data to help answer questions about the use of higher ethanol blends in both vehicles and off-road engines. They want to know whether E15 and E20 have any adverse impacts on tailpipe emissions, exhaust temperatures, catalytic converters, and engine performance and durability.

> **"Using ethanol blends of 15% and 20% had no significant immediate impact on the vehicles in the initial study."**
>
> **Keith Knoll,**
> NREL project leader

"So far, nothing has jumped out at us, and using ethanol blends of 15% and 20% had no significant immediate impact on the vehicles in the initial study," says Keith Knoll, senior project leader in the Fuels Performance Group of NREL's Center for Transportation Technologies and Systems.

Keith Knoll, senior project leader in NREL's Fuels Performance Group, leads the NREL team that tests cars and other engines that run on fuels containing higher ethanol blends. Photo credit: Heather Lammers/PIX 16891.

A 2003 Buick LeSabre is tested for emissions while running on a gasoline-ethanol blend. In the initial study, most cars adapted well to greater amounts of ethanol, but more research is needed. Photo credit: Keith Knoll/PIX 16926.

Today, ethanol is used widely as a 10% blend in gasoline (E10) to reduce carbon monoxide emissions and smog. And E85 is available on a more limited basis for use in flexible-fuel vehicles. However, EPA regulations do not allow E20 to be used in conventional automobiles. So DOE asked NREL and ORNL to study these mid-level blends to provide important data to decision makers in both industry and government. The resulting data, for example, might justify an EPA waiver to permit more ethanol to be added to gasoline.

In February 2009, NREL updated initial test data on 16 automobiles from model years 1999 through 2007 and on some small, nonroad engines. All the test vehicles experienced some loss in fuel economy, because ethanol has a lower energy density than gasoline. Increases in ethanol and acetaldehyde tailpipe emissions were balanced by reductions in other toxic hydrocarbon emissions.

"The next step is an ongoing, larger study, with more vehicles, that is looking at the long-term effect that ethanol has on catalytic converters and other issues such as drivability, emission controls, and engine durability," Knoll says. "Small nonroad and marine engines may also have trouble with higher ethanol blends, so we'll be conducting more research on them as well."

This work is currently funded through DOE's Biomass and Vehicle Technologies Programs. DOE has made more funding available to accelerate the testing of mid-level ethanol blends in 2010. Ethanol infrastructure is also being evaluated; researchers are studying dispensers, underground storage tanks, and other related equipment. ■

Life Cycle Assessment Determines Sustainability of Biofuels Production

Can the United States produce biofuels sustainably in the year 2022? A team of researchers from NREL's National Bioenergy Center (NBC) and Strategic Energy Analysis Center (SEAC) has found that the answer may be yes—under certain conditions—but that future biofuels production systems will have to be carefully engineered if they are to be sustainable.

The research team created a life cycle assessment (LCA) model to quantify and demonstrate how biomass technologies under development could impact sustainability factors such as greenhouse gas emissions, water use, and fossil energy use, under future production requirements set out in the Energy Independence and Security Act (EISA) of 2007. EISA requires the United States to produce 36 billion gallons of biofuels in the year 2022. Some of this total can come from first-generation biofuels such as corn ethanol, but 22 billion gallons will need to comprise advanced, second-generation biofuels, such as cellulosic ethanol.

"Life cycle assessment of biofuels is a very hot topic. It's important to quantify the greenhouse gas emissions and other sustainability attributes of biofuels, to get an assessment of the true impact," says Andy Aden, an NBC research supervisor who helped oversee the project along with SEAC's Margaret Mann. "We felt it was necessary to put together a life cycle assessment with the best data and see what emissions would look like."

The researchers compared projected greenhouse gas emissions, net energy value, and water consumption for ethanol produced in the year 2022 by five different feedstock-to-ethanol pathways: corn grain-based ethanol produced in an advanced corn dry mill plant; corn stover-, wheat straw-, and switchgrass-based ethanol produced in a biochemical conversion plant; and forest residue-based ethanol produced in a thermochemical conversion plant. The researchers also compared the different ethanol pathways with gasoline to find out whether the second-generation biofuels will be more sustainable than fossil fuels.

"Very few studies are able to compare in this way," says Garvin Heath, who is a primary LCA team member along with David Hsu and Daniel Inman. Other studies may look at only one feedstock, or one sustainability metric, but the NREL study compared multiple feedstocks and metrics simultaneously. "This comparison model is important for DOE's research and development—we can help identify feedstock pathways that may be better performers," Heath explains.

The model results did show that significant greenhouse gas reductions compared to gasoline are possible for the different ethanol scenarios. However, uncertainty analysis indicated that these results would be unlikely for most of the feedstocks and sustainability metrics.

The researchers found that adjusting certain parameters, such as irrigation rate and biomass yield, greatly affected the sustainability of the biofuels production system.

"The system isn't one that lends itself to producing the most sustainable outcome," Heath says. Instead, these results can be used to guide technology development to design systems that will produce the desired outcomes.

Results will be published in a peer-reviewed journal and may be incorporated into LCA models used at other DOE national laboratories, such as Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model, and at the Environmental Protection Agency. In addition, a second phase of the project is underway, which will look at additional feedstocks, other biofuels besides ethanol, and may include data on greenhouse gas emissions from land-use change. ■

NREL Welcomes Tumas as New Center Director

Photo credit: Carol Anna/PIX 16927.

Dr. Bill Tumas recently joined NREL as Center Director for the Chemical and Materials Science Center in Energy Sciences.

Tumas came to NREL from Los Alamos National Laboratory, where he held positions of increasing responsibility since 1994. Most recently, as Program Director of Applied Energy Programs, he was responsible for management, sponsor interface, and development of Los Alamos R&D programs in renewable energy, energy efficiency, infrastructure, and fossil energy.

"I am extremely excited about Bill's willingness to leave Los Alamos and join NREL," says Ray Stults, Associate Laboratory Director for Energy Sciences at NREL. "I have worked with Bill for many years on numerous projects and business development activities, and I am certain he will provide excellent scientific leadership at NREL."

Tumas has extensive research and management experience. He also has a number of publications and patents in several different areas. He received a Ph.D. in chemistry from Stanford University and carried out postdoctoral research at the California Institute of Technology. Prior to Los Alamos, he worked at DuPont Central Research for 6 years. ■

Hawaii Charts a New Course Toward Energy Independence

NREL, in partnership with the U.S. Department of Energy (DOE) and the state of Hawaii, is helping lead the way toward a more secure energy future for the island state through the Hawaii Clean Energy Initiative (HCEI).

Hawaii relies on imported oil for 90% of its energy, placing its economy and environment at risk. Fortunately, the very geography that threatens Hawaii's energy security also provides an abundance of renewable resources that hold the key to its energy independence. By tapping these resources and increasing efficiency, HCEI aims to meet 70% of Hawaii's energy needs with clean energy by 2030.

NREL's Electricity, Resources, and Building Systems Integration Center (ERBSIC) is providing technical assistance to help Hawaii overcome technical barriers to achieving its renewable and efficiency objectives.

To help lay the groundwork for HCEI, NREL is assisting with:

- Policy analysis that helps drive key legislative measures to transform the regulatory environment
- Technical research that identifies where the greatest potential is for energy savings and renewable energy development
- Communications outreach, including a strong brand identity and a robust Web presence that have helped build critical grassroots support with a compelling call to action: "Energy independence … it's up to us."

As the initiative gains traction, ERBSIC is providing technical assistance to help Hawaii overcome technical barriers to achieving its renewable and efficiency objectives.

With support from NREL's Integrated Deployment and Buildings Research groups, ERBSIC is conducting energy modeling to help advance Hawaii's energy efficiency agenda. By running NREL-developed BEopt and Opti-Plus energy modeling software, the team is assisting with efforts to optimize the energy efficiency of residential and commercial buildings and installations, including Fort Shafter, a new military command and control facility.

NREL's ERBSIC team has set up five solar monitoring stations in Hawaii. Photo credit: Paul Norton/PIX 16928.

To help integrate renewable energy into Hawaii's fragmented electric grid infrastructure, the ERBSIC team is also:

- Performing analysis to inform plans for an undersea power cable that would transmit up to 400 megawatts of wind energy generated on Molokai and Lanai to Oahu, where most of Hawaii's energy is consumed
- Using the NREL-developed Hybrid Optimization Model (HOMER) to help Lanai develop a roadmap for becoming a net-zero energy community–that is, a community that produces as much energy as it consumes
- Conducting solar and wind resource modeling to help utility operators adjust for spikes and dips in output so they can better ensure uninterrupted service as they make the transition from petroleum to renewable energy. ■

Parsons Spreads the Word on Wind Power

Brian Parsons, manager of NREL's Transmission & Grid Integration Group, has once again served as guest editor of *IEEE Power & Energy Magazine* for electric power professionals. The November/December 2009 issue is devoted to the integration of wind power–the world's fastest growing renewable energy source–to the electric system.

Parsons co-authored the issue's guest editorial column, "It's in the Air," with Charlie Smith of the Utility Wind Integration Group. In the column, they update readers on the DOE 20% Wind Energy by 2030 report, the North American Electric Reliability Corporation's Integrating Variable Generation Task Force, renewable electricity standards, and the production tax credit. This is the third issue of *IEEE Power & Energy Magazine* devoted to the subject of wind power and co-edited by Parsons and Smith. Other NREL contributing authors include David Corbus and Debbie Lew, who guided a team of writers involved in the wind-integration studies and reported on this effort in an article entitled "Up with Wind." Michael Milligan and Paul Denholm contributed to the article "Wind Power Myths Debunked," which addresses common misunderstandings about wind energy integration. Eduard Muljadi coauthored a generator-modeling article entitled "A Whirl of Activity." Read the issue at www.ieee.org/organizations/pes/public/2009/nov/index.html. ■

NREL Modeling Process Aims to Keep Electric Car Power Trains Cool

NREL engineer Ken Kelly sees a future of thermal control technologies with broad applications that will keep electric car components cool and in good working condition. That vision is much more likely to come true because of a rapid modeling process recently developed by his advanced power electronics research team.

Kelly and his collegues are partnering with automotive manufacturers and suppliers of electronic automotive components to develop technologies that remove the excess heat associated with electric vehicles' power modules.

Power electronics in electric vehicles condition the electrical energy that flows between the vehicle's battery pack and its electric motor. These electronic packages are the focus of research conducted by Kelly and colleague Kevin Bennion. By developing new technologies for cooling such packages, Kelly and Bennion seek to lower costs and ultimately improve the market penetration of electric vehicles.

"Achieving significant national benefits in vehicle fuel savings depends on electrified vehicles achieving substantial market penetration," says Kelly.

To accomplish these goals, electronics packages must be smaller, lighter, and less expensive. They must also handle excess heat generated during the conversion of electrical energy. Unmanaged, the unwanted heat can damage the vehicle's power electronics.

To characterize better ways of managing the heat, Bennion developed the new technique to assess tradeoffs between novel electronics packages and advanced cooling technologies. Kelly and Bennion then worked with engineers at Delphi Corporation to refine and apply the modeling technique to advanced electronics packages that Delphi is developing under a DOE contract.

According to a Delphi spokesperson, "The partnership with NREL provided innovative analytical tools that allowed us to rapidly assess the performance tradeoffs between multiple thermal technologies." In return, Kelly and Bennion gained valuable confidence in their new technique's capability to assess practical, real-world technologies.

Going forward, the new modeling technique will support collaborations—among NREL, industry, and other federal labs, including Oak Ridge National Laboratory—to develop cooling alternatives for advanced power electronics packaging technologies. ■

NREL PV Incubator Helps Boost Solar Start-Up

Try taking a 4-foot-by-2-foot piece of glass and turning it into a solar panel in 2 hours—at manufacturing costs below $1 per watt.

That's just what Colorado-based Abound Solar has done, using a fully automated manufacturing process with roots dating back to 1993 when scientists at Colorado State University (CSU) first started working with NREL.

"This manufacturing process is based on 15 years of development at CSU by Abound's three founders and the key support of NREL," says Kurt Barth, an Abound founder and senior technologist.

The Abound/CSU team worked with NREL through its Photovoltaic (PV) Technology Incubator program. The goal of this program is to shorten the timeline for companies to transition prototype and pre-commercial PV technologies into pilot and full-scale manufacture.

"Companies are partnered with experts and capabilities at NREL, which reduces project implementation risk, quickly overcomes R&D hurdles, and increases the likelihood that performance and reliability objectives can be achieved," says NREL Senior Supervisor Martha Symko-Davies.

Senior Project Leader Harin Ullal is one of many NREL scientists who have worked closely with the CSU/Abound team throughout the years. "Abound Solar deposits its semiconductor layers very rapidly—in a matter of few minutes—compared to other PV companies," says Ullal.

Prior to initiating its PV incubator program subcontract in 2007, Abound (then named AVA Solar) had 33 employees. In 2009, after the successful completion of the program and a large infusion of private-sector funding, Abound had about 230 employees. ■

In 2009, Abound opened a large-scale production facility in Longmont, Colorado. The ribbon-cutting ceremony featured, from left, Congressman Jared Polis, Abound CEO Pascal Noronha, Abound Chairman of the Board John Hill, Colorado Governor Bill Ritter, NREL Director Dan Arvizu, and EUROSOLAR President Hermann Scheer. Photo credit: Dan Bihn/PIX 16735.

Jacobs Advises FERC's New Office of Energy Policy and Innovation

Mike Jacobs of NREL's Electricity, Resources, and Building Systems Integration Center is helping to improve technical efficiency across the Federal Energy Regulatory Commission's (FERC) regulated industry. Working out of Washington, D.C., Jacobs is advising the FERC's new Office of Energy Policy and Innovation on technical matters, such as the integration of renewable resources, the deployment of demand response and distributed resources, energy efficiency, transmission issues, smart grid standards, and other advanced technologies. The office, established by Chairman Jon Wellinghoff in May 2009, is tasked with issuing, coordinating, and developing proposed policy reforms to address emerging issues affecting wholesale and interstate energy markets.

Jacobs has experience in defining transmission rights for direct-current transmission, establishing interconnection rules for wind, including low voltage ride-through standards, and developing conditional firm transmission service. Prior to joining NREL, Jacobs was vice president of transmission for First Wind, an independent developer and owner of wind energy projects throughout North America, and acting policy director with the American Wind Energy Association in Washington, D.C. ■

Coolerado Is Cool for Air-Conditioning

The 5-ton H80 hybrid commercial rooftop air-conditioning unit developed by Coolerado Corporation was the first winner of the University of California–Davis Western Cooling Challenge in August 2009. NREL helped Coolerado develop its innovative cooling core, and provided testing and analysis of early prototypes, as well as of the initial product offering.

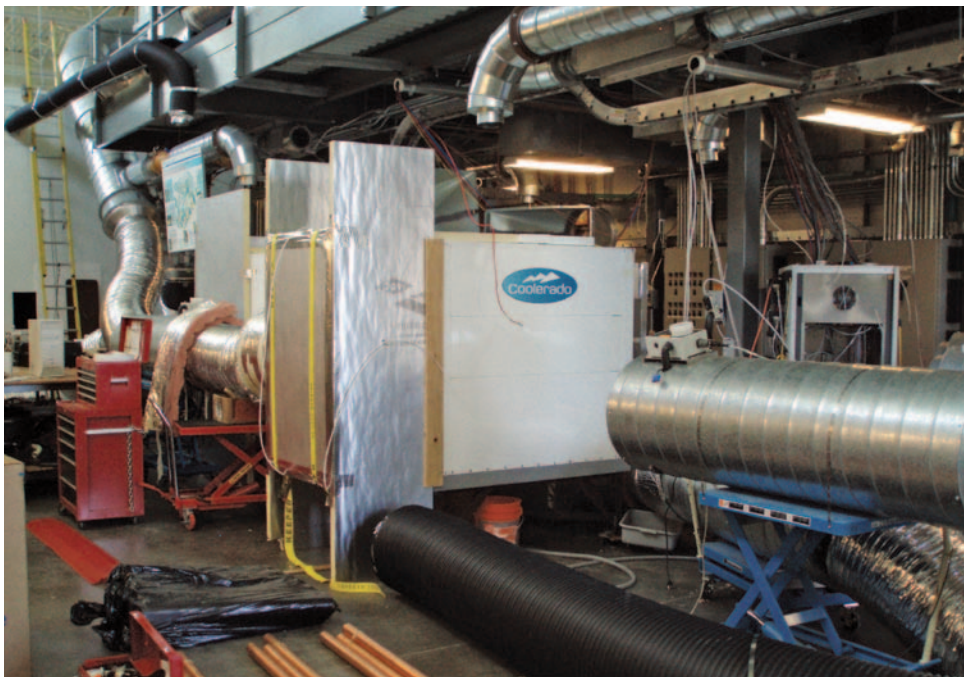
NREL continues to work with Coolerado to test its latest product lines through the Western Cooling Challenge. The Challenge encourages air-conditioning manufacturers to deliver better products and to help building owners install and use those products in new and existing low-rise, nonresidential buildings. It is based on the premise that, because many western states are dry, building owners should use cooling units that are specific to dry climates.

"NREL has been involved with Coolerado almost from the beginning, when we tested some of its early stand-alone prototypes and observed impressive thermodynamic performance. We are pleased to work with Coolerado again," says Ron Judkoff, NREL principal program manager for buildings research, development, and demonstration.

"Our Advanced HVAC Lab was used for rigorous tests of the H80 hybrid conditioner, and it exceeded our expectations. The energy savings target from the Western Cooling Challenge was to be 40% better than the 2010 standard; our tests show almost 80% energy use savings and more than 60% peak demand reduction," says Eric Kozubal, senior engineer in charge of testing.

The H80 works by drawing fresh outdoor air into a two-stage air-conditioner through an outside air damper (because outside summer air may be as warm as 110°F). The air is filtered, then enters the patented heat and mass exchange process. This process cools about half the air, through a series of direct and indirect evaporative cooling cycles, down to about 72°F on the dry or indirect side. This air is then directed through the cooling coils of the air conditioner for further cooling to about 55°F and is dehumidified before it enters the living space. The Coolerado H80 has enough cooling capacity to serve up to 3000 ft^2 of floor area.

The other half of the air has had water added to it and thus been cooled to about 79°F via direct evaporative cooling. It is used to cool the condenser, compressor, and exhaust fan before it exits the building. Under milder conditions, or under mixed air conditions, only the first stage of the conditioner is needed. This saves even more energy. See the Coolerado Web site, www.coolerado.com/, for additional information on the H80. ■



The Coolerado H80 cooling unit was tested at NREL's Advanced HVAC Lab. Photo credit: Coolerado Corporation/PIX 16929.

Big Demand for NREL's PV Technologies

Nearly two-thirds of NREL's active photovoltaic (PV) patents have been licensed by industry—which is why NREL is widely recognized as setting industry standards for PV licensing.

NREL's number of active license agreements for PV-related technologies now stands at 39 (with 37 distinct companies). Notable among these are Global Solar Energy and PrimeStar Solar.

- Global Solar Energy, currently the largest manufacturer of copper indium gallium di-selenide (CIGS) thin films on a flexible substrate, holds one of the first licenses for NREL's CIGS technology. NREL developed a laboratory procedure to produce CIGS solar cells with 20% solar-to-electricity conversion efficiencies using glass as a substrate. Global Solar applies the same procedure, but instead deposits the coating on roll-to-roll production process.
- PrimeStar Solar has licensed the world-record-efficiency, thin-film cadmium telluride (CdTe) PV technology that NREL developed. GE Energy is PrimeStar's majority shareholder, which bodes well for moving low-cost CdTe PV modules to market. Solar is playing an increasing role in GE Energy's renewable energy portfolio and is expected to grow even more as energy costs continue to rise.

NREL's Commercialization & Technology Transfer Program has a strong track record of success. Over the past 10 years, more than 400 new records of invention have been disclosed to NREL, resulting in nearly 300 active patents and patent applications and almost 100 active license agreements.

When NREL licenses its inventions and technologies to private-sector companies, a raft of good things is set in motion.

First, a state-of-the-art technology, one that likely has been in the development cycle for years, is given its best chance to stand or fall in the marketplace.

NREL is widely recognized as setting industry standards for PV licensing.

Second, the government retains access to the technologies for further research via an irrevocable, nonexclusive, nontransferable, royalty-free license that NREL holds for the government in each of its license agreements.

Finally, NREL and its inventors receive royalties from the sale of products, which provides a return on the taxpayers' investment in federally funded research and development and provides further incentive for researchers to report new inventions. ■

Applications for Global Solar Energy's CIGS PV products run the gamut in size from the 750-kilowatt PV array field at the company's headquarters in Tucson, Arizona, to the 6.5-watt highly portable module shown charging an iPod. *Photo credits: (top) Renewable Ventures, a Fotowatio Company/PIX 16930; (bottom) Global Solar Energy, Inc./PIX 16931.*

Photo credit: Dean Armstrong/PIX 16932.

Mariellen Conroy Brings Extensive Proposal Management Expertise to NREL

In October 2009 Mariellen Conroy was hired as NREL's new Administrator for Opportunity and Proposal Management. Conroy spent the past 10 years at CH2M Hill where she managed proposals for the federal business development services department. She has extensive experience in private sector proposal coordination and has managed or supported proposals ranging in size from $500 million to several billion dollars in contract value for a wide range of clients including the U.S. Department of Energy, U.S. Army Corps of Engineers, Federal Energy Management Association, NASA, and the Air Force Center for Environmental Excellence.

NREL's Proposal Management Office is responsible for creating a business growth approach and proposal development process that is professional, focused, and consistent. Conroy will manage and track new business opportunities, supporting both centralized and distributed laboratory growth planning and management, and will be a corporate lead for proposal development activities. ■

NREL Dives Into Water Power Research

For more than 2 decades, researchers at NREL's National Wind Technology Center have led U.S. efforts to tap into our nation's vast wind energy resources by developing advanced wind energy technologies. Now, NREL is turning this wind-energy expertise toward a new wave of renewable energy technologies: wave, tidal, river current, and ocean thermal energy conversion.

Just like wind turbines, these technologies (sometimes referred to as marine hydrokinetic energy technologies) convert the kinetic energy of a moving fluid into electrical energy from one of the Earth's largest, most predictable, and renewable resources—its oceans and rivers. According to the International Energy Agency (IEA), the Earth's oceans can produce more electrical energy than the total sum of every other form of energy in use today.

The objectives of NREL's water power R&D efforts are to accelerate the development and deployment of marine and hydrokinetic technologies by providing industry with the support it needs to validate machine performance, increase device efficiency and capacity factors, and reduce capital costs. This is expected to increase investor and regulator confidence and lead to the development of the first U.S. marine energy companies to have a significant impact on the market by 2015.

"NREL is turning its wind-energy expertise toward a new wave of renewable energy technologies—wave, tidal, river current, and ocean thermal energy conversion."

To accomplish these objectives, NREL will use its working relationships with the ocean energy industry and regulating agencies, as well as its extensive technical and engineering experience and project management skills, to bring together a global team of marine energy research experts. Team members will include researchers from national laboratories, the IEA Ocean Energy Systems Implementing Agreement, device developers, universities, and government agencies.

A key player in water-power research, NREL is the technical administrator and founder of the International Electrotechnical Commission's U.S. Technical Advisory Group to develop standards for the wave and water current energy industry. NREL has also been a member of the IEA Ocean Energy Executive Committee since 2004 and led the nation's ocean thermal energy conversion research efforts in 1984. ■

Photo credit: iStock_2364078.

NREL RASEI Fellows Provide Horsepower for New Renewable Energy Institute

Sixteen NREL experts from across the renewable energy disciplines were recently named as Fellows of the new Renewable and Sustainable Energy Institute (RASEI). They join 18 Fellows from the University of Colorado-Boulder in helping to guide the interdisciplinary joint research effort between the two institutions.

NREL and CU-Boulder signed the agreement forming RASEI in June 2009. RASEI's mission is to advance solutions for producing energy economically from low-carbon sources, decreasing reliance on foreign oil, reducing greenhouse gas emissions, and using energy more efficiently to meet the global energy challenge.

Partners Focus on Advancing Clean Energy Technologies

Dr. Robert McGrath, NREL deputy laboratory director for science and technology and one of RASEI's chief architects, says that RASEI "enables CU-Boulder and NREL researchers to take full advantage of the complementary strengths resident within each institution."

Colorado Gov. Bill Ritter adds, "RASEI is poised to attract the best and brightest new research talent to the state of Colorado, which will also bring good jobs and advance clean energy technologies."

In addition, RASEI builds on and expands the work of the Center for Revolutionary Solar Photoconversion, the Colorado Center for Biorefining and Biofuels, the Center for Research and Education in Wind, and other research centers affiliated with the Colorado Renewable Energy Collaboratory.

> "RASEI is poised to attract the best and brightest new research talent to the state of Colorado, which will also bring good jobs and advance clean energy technologies."
>
> **Bill Ritter**
> Colorado governor

RASEI to Study Plug-In Hybrids at High Altitude

Starting in early 2010, RASEI will be working with Xcel Energy and Toyota Motor Sales, USA (TMS) to gather data on the performance of 10 plug-in hybrid electric demonstration vehicles that will be charged using Boulder, Colorado's "SmartGridCity" technology. RASEI researchers want to know when and where consumers choose to recharge the vehicles' battery packs, and how Smart Grid technology may influence consumer decisions in "real-world" conditions.

The goal of the RASEI/Xcel/TMS project is to obtain and analyze data on vehicle performance and charging patterns, consumers' behavior and preferences, and interactions between customers and the electric utility. Carrying out the project in Boulder allows the researchers to see how Toyota's first-generation lithium-ion battery will fare in plug-in hybrids operating at high altitude.

As the first of its kind in the United States, the SmartGridCity project is designed to increase the reliability and efficiency of the utility grid by showing how customers actually use energy. And the project allows customers to control in-home energy management devices remotely. Tony Markel, a project leader in NREL's Transportation Technologies and Systems Center, says, "This joint project is the first to analyze how advanced vehicles interact with a smart grid, and we're glad to be a project partner."

For more information about RASEI, visit http://rasei.colorado.edu. ■

NREL RASEI Fellows

- Howard Branz, National Center for Photovoltaics
- Al Darzins, National Bioenergy Center
- Maria Ghirardi, Biosciences Center
- David Ginley, National Center for Photovoltaics
- Michael Himmel, Biosciences Center
- Chuck Kutscher, Electricity, Resources, & Building Systems Integration Center
- Angelo Mascarenhas, Chemical & Materials Science Center
- Patrick Moriarty, National Wind Technology Center
- Robin Newmark, Program & Strategic Decision Support
- Arthur Nozik, Center for Revolutionary Solar Photoconversion
- Brian Pivovar, Hydrogen Technologies & Systems Center
- Mike Robinson, National Wind Technology Center
- Garry Rumbles, Energy Sciences
- John Turner, Hydrogen Technologies & Systems Center
- Jao van de Lagemaat, Chemical & Materials Science Center

Photo credit: Toyota Motor Sales, USA/PIX 16933.

NREL Scientists Pave the Way toward More Reliable Thin-Film Solar Cells

For more than a decade, NREL has conducted an aggressive and highly productive research program in thin-film photovoltaics (PV). In one of the program's most recent accomplishments, NREL scientists Dave Albin and Joe del Cueto have devised an important new analysis method. That method, combined with accelerated lifetime testing, gives researchers a better way to study stabilization of thin-film PV devices—and help improve reliability and lower costs.

> "We expect this approach to become a key technique for improving thin-film solar cell reliability."
>
> **Dave Albin,**
> NREL scientist

Until recently, most PV systems, which convert sunlight into electricity using solar cells, were based on single-crystal silicon—but the relatively high cost of these PV systems has discouraged widespread use. The PV industry is now manufacturing and marketing more exotic, thin-film materials that not only perform well, but are also cheaper to make.

However, questions persist about the long-term reliability of these thin-film PV products.

Albin and del Cueto's new technique assesses deterioration in thin-film cells and modules by measuring capacitance, or the capability to store an electric charge, as it changes during accelerated stress testing. This work is unique in that it focuses on capacitance hysteresis—that is, the difference in capacitance obtained using both forward and reverse-direction voltage scans. Nearly all studies before Albin and del Cueto's ignore hysteresis.

"This method for studying degradation in thin-film products is revolutionary—it's quick, nondestructive, and capable of probing minute changes in the chemical and electronic nature of both solar modules and individual solar cells," Albin says. "We expect this approach to become a key technique for improving thin-film solar cell reliability."

Albin and del Cueto presented their method at a recent international optics and photonics conference. ■

At NREL's Outdoor Test Facility, scientists test the reliability of photovoltaic modules and systems outdoors, as well as indoors using highly controlled laboratory and test conditions. Photo credit: Patrick Corkery/PIX 14767.

Predicting Fuel Economy of Plug-in Hybrids Gets Easier

Plug-in hybrid electric vehicles (PHEVs), which can be recharged using standard electrical outlets, offer significant flexibility and benefits over traditional vehicles. Like electric vehicles, PHEVs can be powered by electricity alone. Like hybrid electric vehicle (HEV) engines, PHEV engines enable greater driving range. And, PHEVs have the potential to slash our dependence on imported oil. Until recently, however, quantifying their fuel economy was challenging.

NREL engineers Jeff Gonder and Aaron Brooker have developed a novel method for estimating the electricity and fuel consumption of PHEVs in real-world operating conditions. "Our method involves adjusting the standard test cycle results from each mode of PHEV operation—whether the vehicle is using electricity from its battery or gasoline from its tank," Gonder says. "The adjusted values are then combined into a single fuel economy prediction."

This method—and the subsequent collaboration with two other national laboratories—has attracted lots of media attention as car makers prepare to release PHEVs into the marketplace.

Idaho National Laboratory (INL), which monitors fuel use in advanced technology fleets, has accumulated more than a year's worth of data on about 100 PHEVs of the same design. Argonne National Laboratory (ANL) has collected laboratory test data on the same type of PHEV to evaluate data collection procedures on standardized driving tests.

"We applied our adjustment technique to PHEV data from ANL laboratory testing and compared the fuel economy predictions to on-road data from INL's large fleet evaluation effort," Gonder says. "After accounting for how frequently the PHEVs in the fleet actually plug in, we found excellent agreement between the adjusted test cycle predictions and actual fuel and electricity use."

The adjustment method predicted that the PHEV would consume about 1,300 kilowatt-hours (kWh) of electricity per year and save an average of 50 gallons of fuel per year, compared to an efficient HEV. The fuel savings for an individual PHEV, however, can deviate significantly depending on how the vehicle is driven. For instance, the same vehicle driven less aggressively and recharged every 30 miles could save more than 200 gallons of fuel per year, compared to an HEV, at a total cost of roughly 2,700 kWh of electricity. ■

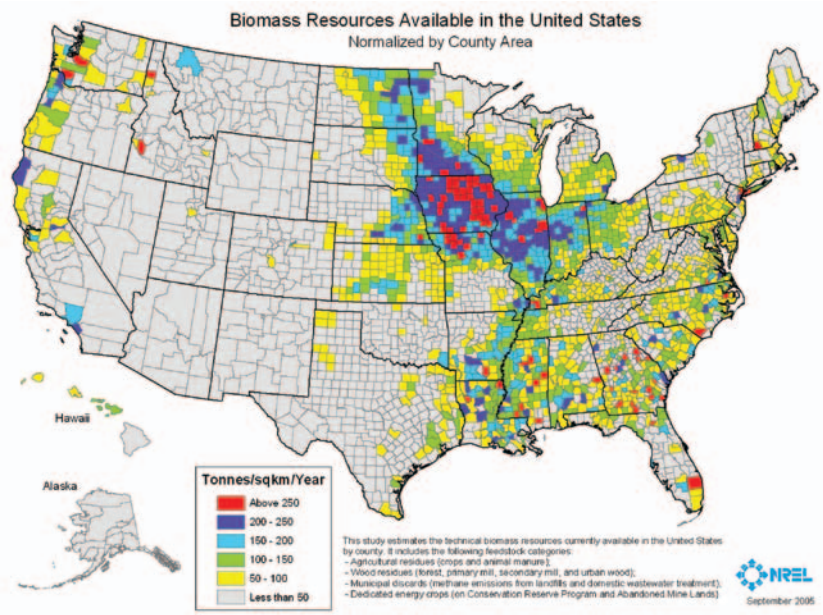
State Bioenergy Primer Report Released

States are looking for ways to tackle their energy, environmental, and climate change challenges through a variety of approaches, and biomass often takes center stage. There is a lot of information on biomass available from many sources, but most of that information focuses on only one feedstock.

To solve this problem, NREL partnered with the Environmental Protection Agency to publish a guidance document, "State Bioenergy Primer: Information and Resources for States on Issues, Opportunities, and Options for Advancing Bioenergy." The report provides targeted information that will help state decision makers determine if they want to pursue bioenergy production.

Biomass can be used to produce transportation fuel, heat, electric power, or other products; it currently represents about 3%-4% of the United States' total energy production. The benefits of increasing biomass use, which can depend on the intended use and source, include improved energy security; increased economic development and job growth; and expanded environmental benefits, including reduction of greenhouse gas emissions.

Along with the opportunities, of course, come potential challenges that vary by state. Infrastructure constraints and land-use impacts are among the top considerations; each state's geography, market conditions, and incentives and regulations impact which bioenergy methods make sense for that state to pursue.



The State Bioenergy Primer estimates the biomass resources currently available in the United States by county. Source: NREL 2005.

Read the report on the Environmental Protection Agency Web site: www.epa.gov/cleanenergy/documents/bioenergy.pdf ■

Solar Technology Acceleration Center Powers Up

Ground was broken for one of the world's largest solar test and demonstration facilities in Aurora, Colorado, on October 21, 2009. The Solar Technology Acceleration Center (SolarTAC) is a collaboration of six public and private sector entities that joined forces to build a site where member companies can bring their early commercial or near-commercial stage solar technologies for testing and demonstration under actual field conditions. Those entities are Abengoa Solar, the City of Aurora, the Colorado Renewable Energy Collaboratory, Midwest Research Institute (MRI), SunEdison, and Xcel Energy.

NREL participates in SolarTAC as a member of the Colorado Renewable Energy Collaboratory and in October announced that it signed a letter of intent to join SolarTAC as a member. NREL membership in SolarTAC will allow the national laboratory to better engage with industry to solve challenges in increasing the amount of solar electricity produced in the United States. Among other projects, NREL will install a $2 million pilot-scale advanced thermal energy storage test and evaluation facility at SolarTAC to help improve heat storage technologies.

Among the 150 participants at the SolarTAC groundbreaking were Aurora Mayor Ed Tauer, Colorado Gov. Bill Ritter, and Xcel Energy CEO Dick Kelly.

> **"SolarTAC takes renewable energy from a nice idea to a real-world impact."**
>
> **Ed Tauer**
> Aurora, Colorado, mayor

Tauer kicked off the groundbreaking by noting the economic impact of SolarTAC and the emerging solar industry. "SolarTAC takes renewable energy from a nice idea to a real-world impact. It's a company's secret weapon for creating commercially successful business," said Tauer.

"We welcome SolarTAC into Colorado's New Energy Economy ecosystem," said Governor Ritter. "The testing and research conducted at this facility will tie in well with the state's solar industry, further enhancing Colorado's position as a gateway for high performing solar products that lower energy costs while drawing more companies and clean energy jobs."

"SolarTAC will be an important part of finding real world solutions to developing solar power," said Xcel Energy CEO Kelly. "We believe that through SolarTAC, we will develop technologies that are more efficient, reliable, and cost effective and will allow us to use more of this abundant, clean energy resource to meet our customers' future energy needs."

By the end of this year, nearly $1.8 million of infrastructure work will be completed by MRI, SolarTAC's management and operating contractor, to prepare the site for member companies to move in equipment and construct member-specific facilities. The work includes grading, drainage and soil erosion control, access roads, electric power supply and distribution, fire protection, sewer and water lines, communications lines, fencing, and security. ■

NREL Celebrates Turbine Installations

Colorado Gov. Bill Ritter, NREL Director Dan Arvizu, and senior vice president of Siemens Energy Inc., Barry Nicholls, flip a giant symbolic switch to commemorate the commissioning of the 2.3-MW Siemens wind turbine installed at NREL's National Wind Technology Center. The turbine is the centerpiece of the largest government-industry research partnership for wind power generation ever undertaken in the United States. NREL will work with Siemens in this multi-year effort to study the turbine's performance and aerodynamics. "With our partners at Siemens Energy, we will embark on a comprehensive R&D program that will pave the way for the even more advanced wind turbines of the future," Arvizu says.

Photo credit: Lee Fingersh/PIX 16934.

Mark Handschy, senior advisor to U.S. Department of Energy (DOE) Under Secretary Johnson, and Megan McClure, program manager for DOE's Wind and Hydropower Technologies Program, cut the commissioning ribbon to celebrate the installation of the DOE 1.5-MW turbine installed at NREL's National Wind Technology Center (NWTC). The new turbine will be used for long-term research efforts to advance wind turbine performance and reliability and reduce the cost of wind energy. "This turbine provides the foundation for long-term collaborative research with our DOE, university, and industry partners," says Fort Felker, director of the NWTC.

Photo credit: Joe Poellot/PIX 16935.

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Editor's Note: In the article, "NREL Researcher Serves as Guest Editor for *IEEE Power & Energy Magazine*" (*Energy Innovations* Fall 2009, pg. 7), we incorrectly identified NREL's Distributed Energy Resources Test Facility. We apologize for any confusion this may have caused our readers. ■