NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Energy Innovations
Science & Technology at NREL

Winter
2011

Solar technologies win two R&D 100 Awards

NREL researchers to test largest turbine yet

Hawaiian hybrid initiative fueled by NREL

and more.

Published by the National Renewable Energy Laboratory

IBRF Boosts Biorefinery R&D to Drive Technology to Market

The new Integrated Biorefinery Research Facility (IBRF) offers an unprecedented level of flexibility for NREL's science and technology experts to develop cost-effective biofuels processes and move them into the marketplace faster. The pilot plant expansion, Stage I of which was completed in August 2010, significantly improves the biofuels research and development capabilities at the laboratory.

The centerpiece of the IBRF is the set of parallel "process trains", composed of pretreatment and enzymatic hydrolysis reactors that break down biomass from a cellulosic feedstock into sugars that can be fermented into ethanol. Each process train handles up to 1 dry ton of feedstock per day and can be operated in multiple configurations.

The first pretreatment reactor installed in the IBRF can test a variety of pretreatment chemistries over a broad range of reaction conditions, allowing researchers to tailor a process to handle specific feedstocks or yield desired products. Enzymatic hydrolysis reactors enable semi-continuous processing of pretreated materials with high solids content, which is a key factor in reducing conversion costs.

"The IBRF provides us with considerably greater flexibility to configure, test, and prove out a range of leading biochemical processing routes to cellulosic ethanol and other advanced biofuels," says Jim McMillan, NREL's biochemical process R&D manager.

The improved capabilities allow NREL to help industrial partners solve the unique problems they face scaling up their proprietary biofuels processes. Beyond allowing partners to leverage NREL's equipment and expertise, the IBRF has enough room for them to bring in their own equipment for stand-alone or integrated testing and development.

"We can accelerate biofuels research, development, and demonstration progress by supporting a wider variety and number of industry-driven projects," McMillan says.

The IBRF will be used to demonstrate that cellulosic ethanol can be cost-competitive with conventional gasoline by 2012. It will also support the goals of the Energy Independence and Security Act of 2007, which requires U.S. production of 36 billion gallons of renewable fuels by 2022.

Stage II includes adding the second pretreatment and high solids enzymatic hydrolysis process train, constructing administrative offices, and modifying several supporting laboratories. Based on NREL's utilization of a fast-track design/build implementation approach, these additions are scheduled to be completed and operational in summer 2011.

Master technician and pilot plant operator Robert Lyons inspects the high-solids pretreatment reactor in the Integrated Biorefinery Research Facility. The new reactor greatly enhances NREL's pretreatment testing and process development capabilities.

Improved TCOs Advance Commercial Success of Thin-Film PV Cells

The thin-film solar cells in use today could not function without transparent conducting oxides (TCOs). TCOs are deposited on either glass or device active layers and are used to form the front of the solar cell. Improving the quality and properties of TCOs is widely recognized as a near-term avenue to enhance module performance and advance the commercial success of thin-film photovoltaics (PV).

A group of NREL scientists has done just that. In a recently published study, they identified a pathway to producing better TCO films that demonstrate higher infrared transparency. They showed that controlled variation in the real part of the dielectric permittivity (which relates to a material's ability to transmit or "permit" an electric field) of typical TCO films can have a profound effect on the optical properties of the material. Prior to this work, dielectric permittivity was assumed to be similar for all TCOs and was not considered a variable parameter.

Global Solar Energy/ PIX13413

Thin-film copper indium gallium selenide (CIGS) PV creates a lightweight power supply that travels easily.

> **"This finding surprised everyone. We are modifying the TCO environment in ways that didn't seem possible a few years ago."**
>
> **Tim Gessert**
> NREL principal scientist,
> Thin Film Technologies Group

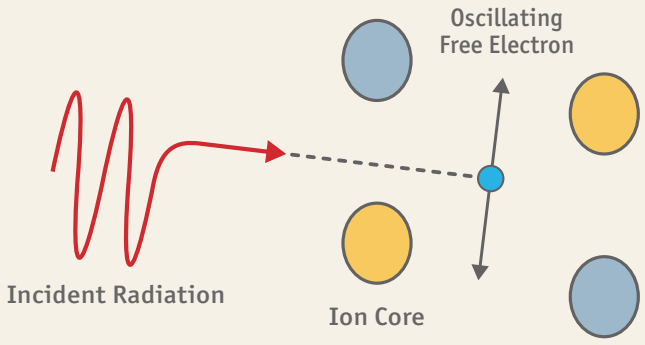
"This finding surprised everyone," said Tim Gessert, who leads NREL's Thin-Film Technologies group. "We are modifying the TCO environment in ways that didn't seem possible a few years ago."

Free electrons tend to resonate (or wiggle) within a TCO, which can be detrimental to a PV device's performance. "We can't stop this from happening, but with this discovery, we can move the resonance point out farther into the infrared where the solar cell is not designed to respond because there is so little light energy," said Gessert.

NREL scientists believe that TCO films with permittivity control may have advantages that could be exploited at a commercial scale. Projections show that within 10 years, half of all glass manufactured could be used for PV applications. The glass manufacturers of the world are keenly interested in developing value-added products specifically for the PV market. NREL has filed several patents related to this TCO work and has long-term working relationships with several major glass companies.

These companies need to identify not only what mechanical and optical properties the glass needs to have, but what kind of TCO to put on the glass. Glass accounts for close to half of the cost of manufacturing some commercial thin-film PV cells, so improvements in this aren a will translate to lower costs of the final PV product.

Beyond this, the new findings may hold even greater significance for other TCO materials that have industrial advantages, but in which the optical transmission remains limited by low electron mobility.

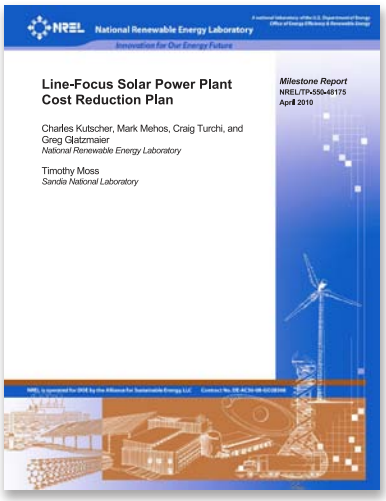


Functional schematic illustration of infrared light interacting with a free electron in a transparent conducting oxide. Findings related to this work have immediate application to improving thin-film solar cells.

NREL Research Shows How to Reduce the Cost of Line-Focus Solar Power Systems

Becoming competitive with fossil fuels

Reducing the cost of concentrating solar power (CSP) is a recognized need. The U.S. Department of Energy (DOE) assigned NREL the task of developing a roadmap for reducing the cost of line-focus solar power systems. Line-focus collectors are the most mature CSP technology but significant opportunities still exist for near-term cost reduction.



NREL analysts reviewed earlier plans, investigated current system costs, and developed appropriate cost targets. They then looked at which subsystems and components had the greatest opportunity for cost reduction and identified the various ways these reductions could be achieved. Specific tasks were developed for the various cost reduction opportunities. Analysts also generated budget estimates for these tasks, and levels of priority were assigned to them. The tasks, priorities, and budgets were summarized in a detailed chart covering FY 2010 through FY 2016 (which is the year the current 30 percent investment tax credit is slated to expire). All this information was published in a 40-page roadmap document reviewed by DOE and industry stakeholders.

"NREL analysts showed that to be competitive against fossil fuels, solar field costs must continue to decline and overall system performance must improve. Advanced optical and thermal storage materials R&D currently underway at NREL is geared toward achieving these objectives," says Mark Mehos, NREL Program Manager for CSP. "This roadmap provides specific guidance about where and how these cost reductions can be achieved for line-focus collector systems and lays out a multi-year plan for achieving them."

The plan provides valuable information for generating annual operating plans and multi-year program plans, as well as a measuring stick against which progress can be compared. The roadmap is available in the publications section of *www.nrel.gov*.

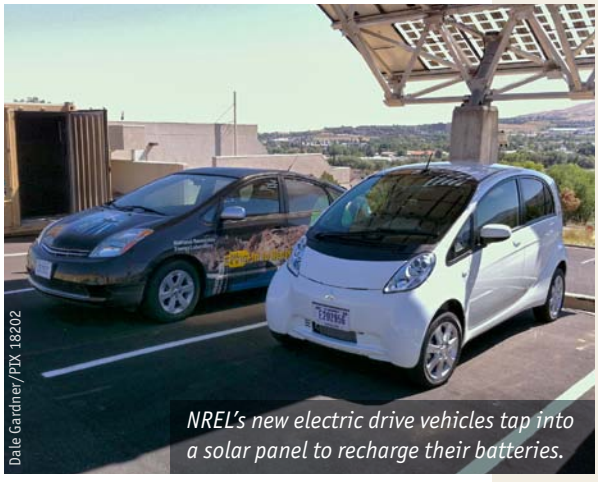
NREL Analyzes Impact of Climate Control in Electric Drive Vehicles

What's the first thing you do after starting your car on a hot day? Turn on the air conditioning (AC). But in plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs), the expectation is for the stored electrical energy in the battery to drive the electric drive motor. Using the battery for immediate AC or heat reduces the vehicle's charge-depleting (CD) range (i.e., the distance over which the vehicle operates on battery power alone).

NREL engineer Robb Barnitt led the effort to quantify the impact of thermally preconditioning the vehicle cabin and battery pack of PHEVs and EVs using off-board power supplied by the utility grid. His team simulated vehicle performance with and without thermal preconditioning over various drive cycles and ambient temperature scenarios.

"We knew that climate control loads would have an impact on CD range, but were surprised by the magnitude" says Barnitt. "We found that climate control loads can reduce CD range by 35%, but that thermal preconditioning can partially restore CD range by up to 19.2%."

Preconditioning the battery also has a positive impact. "Our findings indicate that battery-capacity loss over time is driven by ambient temperatures rather than climate control loads, but that pre-cooling the battery can reduce capacity loss by 7%," Barnitt says.


Dale Gardner/PIX 18202

NREL's new electric drive vehicles tap into a solar panel to recharge their batteries.

NREL's Advanced Technology Vehicle Fleet

NREL's advanced technology vehicle fleet serves as a showcase for visitors and a test bed for research and development. The vehicles feature promising technologies to increase efficiency, reduce emissions, and utilize renewable energy without sacrificing safety or comfort. NREL performs a variety of tests to evaluate their performance and help guide technology development programs.

NREL researchers now have access to two new vehicles. A Mitsubishi iMiEV electric vehicle, one of only 31 in the United States, provides an ability to evaluate fast charge impacts on grids and batteries. In addition, as a result of the Renewable and Sustainable Energy Institute (RASEI) activities of NREL and CU-Boulder, a pre-production Toyota Prius plug-in hybrid electric vehicle, one of 150 in the nation and of 18 to be demonstrated in Boulder, will contribute to transportation research program activities. NREL plans to add at least two more plug-in electric vehicles to the fleet later this fiscal year.

NREL Teams Advance Hydrogen Production, Reduce Costs

NREL research is finding new and improved ways of increasing hydrogen (H_2) production and lowering costs using biology. Hydrogen has the highest energy density on a molar basis of any fuel and its biological production has a small environmental footprint. NREL research is leading the way to developing the technical foundation to support its widespread use.


Jack Dempsey, NREL/PIX14575

NREL's Pin-Ching Maness examines a bioreactor that ferments agricultural and paper residues with a cellulose-degrading bacterium, Clostridium thermocellum.

Principal Scientist Pin-Ching Maness and her team are increasing the rates and yield of H_2 production by fermentation of lignocellulosic biomass feedstocks using *Clostridium thermocellum*, a bacterium that has one of the highest rates of cellulose degradation among all bacteria. It directly converts the recalcitrant lignocellulose to H_2 in a consolidated approach, in lieu of the expensive two-step process using exogenous cellulases.

Potential biomass feedstocks include agricultural residues, dedicated energy crops, wood residues, and municipal paper waste. Increasing the hydrogen yield from these plentiful, low-cost sources and improving the processing techniques reduces the cost of hydrogen.

The research has two main goals: optimizing fermentation parameters in bioreactors and developing a genetic system to redirect metabolic pathways to improve H_2 molar yield. The NREL team has achieved success in transforming *C. thermocellum*, a critical first step toward genetic engineering to improve yield of H_2. Working with Dr. Bruce Logan of Pennsylvania State University, both teams have achieved very high H_2 molar yield in an integrated system combining fermentation with microbial electrolysis cell.

"Addressing bioreactor process optimization and H_2 molar yield together will improve the techno-economic feasibility of H_2 production through fermentation," says Maness.

Meanwhile, in another approach to advancing hydrogen production, Maria Ghiardi, photobiology group manager and principal scientist, has utilized bioreactor conditions that promote algal growth in thin films to solve one of the major challenges for algal production of hydrogen: the sensitivity of the hydrogen producing enzymes to the presence of oxygen. This biological route to hydrogen redirects light capturing photosynthetic pathways to split water to produce hydrogen. A major technical roadblock for photobiological algal production of hydrogen is that photosynthesis also produces oxygen, which is highly inhibitory to the hydrogenase enzymes that produce hydrogen.

> **"This is quite an achievement and has implications for the cost. Potentially, this is a very efficient system."**
>
> **Maria Ghiardi**
> Photobiology group manager and principal scientist

The immobilized thin-film algal bioreactor meets the challenge of preventing oxygen inactivation of the hydrogenase by promoting oxygen use and uptake by respiration in the immobilized algal thin films. The immobilized algae concept represents major progress in developing a low-cost, photobiological H_2-producing system.

"This is quite an achievement and has implications for the cost," Ghirardi said. "Potentially, this is a very efficient system."

Hawaiian Hydrogen Initiative Benefits from NREL Support

NREL analysts within the Hydrogen Technologies and Systems Center support the Hawaii Hydrogen Initiative to understand the infrastructure requirements to expand hydrogen fuel cell vehicles on the island of Oahu.


GM Corp/PIX18203

The Chevy fuel cell vehicle, with Diamondhead in the background, was the first hydrogen-powered fuel cell vehicle on Oahu.

The Gas Company (TGC), Hawaii's natural gas provider, and General Motors (GM) lead the program, which plans to make Hawaii an early pilot market for full-scale launch of fuel cell vehicles by 2015. NREL, which has a history of working with GM and other fuel cell vehicle manufacturers, and Sandia National Laboratories are providing cost and infrastructure analyses.

"We're a natural choice because of our history and understanding of infrastructure needs for fuel cell vehicles," says Marc Melaina of the Hydrogen Technologies and Systems Center.

TGC's Oahu gas pipeline conveys synthetic natural gas (SNG) that contains nearly 10% hydrogen mixed with the SNG. Slipstreams along TGC's 1,000-mile pipeline system could be used to separate the H_2 from the SNG for use at local fueling stations.

NREL Research Results in More Efficient Buildings and Better Modeling Tools

NREL researchers develop tools and strategies that can be immediately deployed to cost-effectively reduce the energy consumption of commercial buildings. Here are some examples of how their work is making an impact today.

Making Older Buildings Better – At the Right Price

Recently, NREL recommended very different strategies to retrofit two buildings under the U.S. Department of Energy's (DOE) Commercial Building Partnerships initiative.

CB Richard Ellis manages 38 million square feet of commercial property in the United States. Working alongside private-sector experts, NREL provided technical assistance for a 20,000-square-foot renovation in a 1980s high-rise. The team's analysis identified a suite of changes resulting in a dramatic 37% energy savings.

For this project, submetering equipment collected data necessary to perform whole building energy modeling-enabling the team to explore many options. They decided upon a range of retrofits addressing air handling units, thermostats, lighting, and plug loads. Combined, these measures have the potential to save almost 7 million kWh of electricity annually if adopted throughout the building.

ProLogis owns more than 300 million square feet of industrial space in the United States. NREL provided technical assistance for a lighting upgrade to a ProLogis 800,000-square-foot unconditioned warehouse.

Through lighting power density calculations, NREL demonstrated that substituting fluorescent fixtures for existing lights reduces energy use by 30% without impacting illumination levels. This change will result in annual savings of almost 1.2 million kWh of electricity. "This lighting retrofit is very cost-effective, with a payback period of less than two years," says Ron Judkoff, NREL's principal program manager for Buildings R&D.

These projects can be replicated in buildings throughout the United States.

Providing the Market with the Right Tools

Whether retrofitting existing buildings or designing new buildings, energy simulation helps identify the most cost-effective, energy-saving measures. NREL enables energy modeling through a new development platform, OpenStudio, for the popular EnergyPlus building simulation software. OpenStudio allows developers to more easily create graphically based applications leveraging the powerful EnergyPlus engine.

> "This lighting retrofit is very cost-effective, with a payback period of less than two years."
>
> **Ron Judkoff**
> Principal program manager, Buildings R&D

OpenStudio has two key attributes to help expand the number of applications for EnergyPlus. First, it's open source to allow a broad community of developers to enhance OpenStudio components. Second, it's cross-platform so that software is written only once for many platforms.

NREL also developed useful tools based on OpenStudio including a plug-in for Google SketchUp, which makes it easy to create building geometry and run EnergyPlus simulations from SketchUp, and ResultsViewer, which displays EnergyPlus results graphically. There's more to come – NREL is planning new tools to help professionals improve the efficiency of buildings.

The Fitzmartin Consulting retrofit project involves renovating one floor of the five-floor HRO law offices in the Wells Fargo Center in downtown Denver, Colorado.

NREL Assists DOE in Reducing Home Energy Use

DOE's Building America Program is an industry-driven research program designed to reduce risks, increase cost effectiveness, and increase the average annual energy savings provided by advanced building technologies in existing and new homes. In Fiscal Year 2010, Building America expanded its focus on retrofits of existing homes and selected 15 new research teams to develop reliable building energy systems that could reduce average home energy use by 40%-100%. NREL's Residential Building Research team managed the Request for Proposal and selection of the teams, and serves as technical monitor for the teams. In addition, NREL hosted Building America's first Residential Buildings Technical Update Meeting, which brought together more than 220 building industry professionals in Denver to discuss successes and challenges in improving energy perfomance of homes.

NREL Researchers Find Huge National Offshore Wind Energy Potential

NREL science and technology experts at the National Wind Technology Center estimate there are 4,150 gigawatts of potential wind turbine nameplate capacity (maximum turbine output) from offshore winds in the United States. The estimate is approximately four times the nation's 2008 electric generating capacity from all sources, as calculated by the U.S. Energy Information Administration. As a result, this estimate and the research behind it, will be used to plan, distribute, and develop future offshore wind power facilities in the United States.

The research is detailed in an NREL report, *Assessment of Offshore Wind Energy Resources for the United States,* and is based on the latest high-resolution maps predicting annual average wind speeds. The report shows the gross energy potential of offshore wind resources.

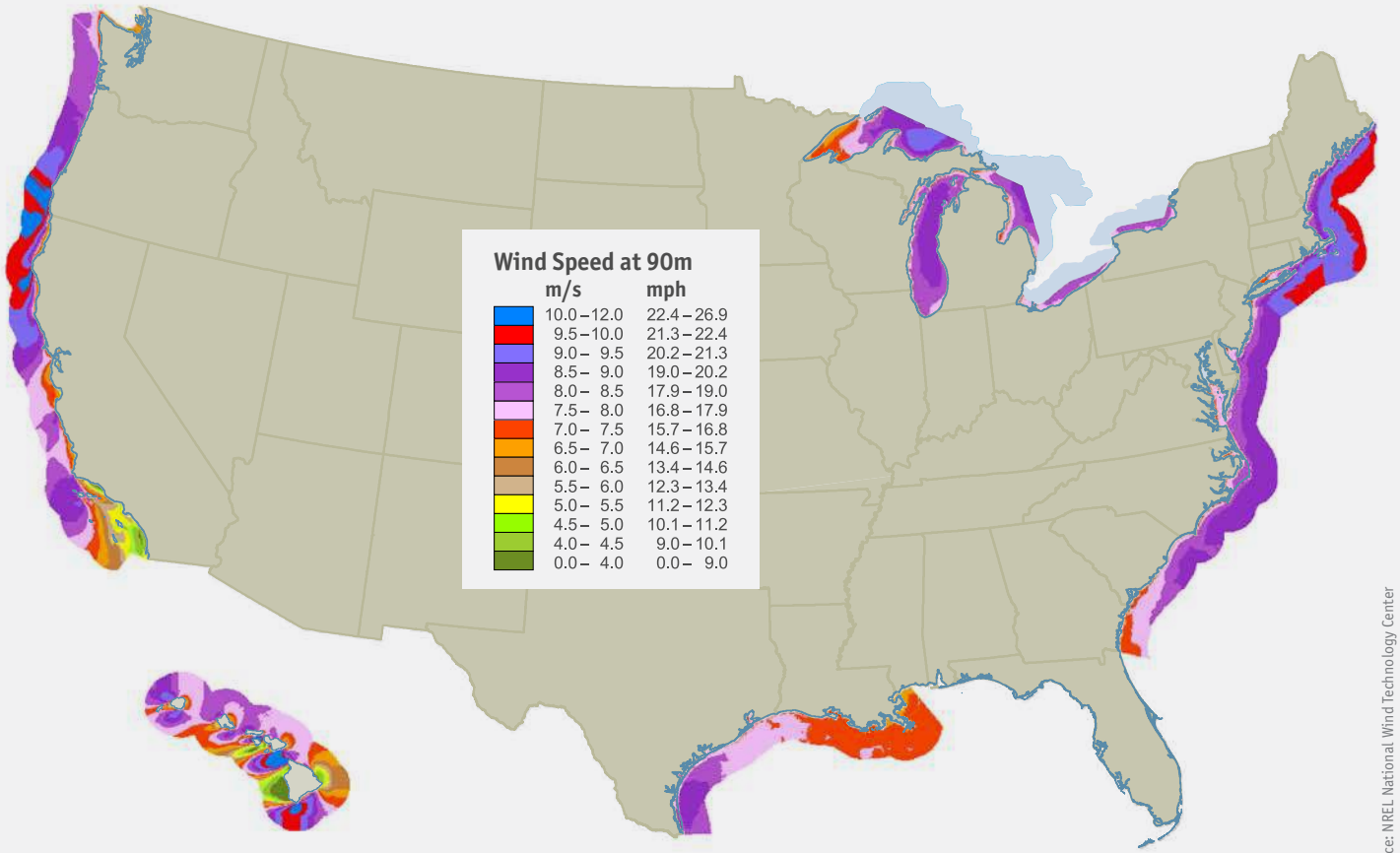
The report contains detailed wind energy resource maps and tables for the offshore wind resources of 26 coastal states bordering the oceans and the Great Lakes. In this report, the potential electric generating capacity was calculated from the total offshore area within 50 nautical miles of shore, in areas where average annual wind speeds are at least 7 meters (m) per second (approximately 16 miles per hour) at a height of 90 m (295 feet). For purposes of this study, it was assumed that 5 megawatts (MW) of wind turbines could be placed in every square kilometer of water that met these wind characteristics.

Offshore wind energy projects totaling more than 5,000 MW have been proposed and are in the planning or development stages in the United States, and interest in offshore wind power development is growing among governments and also in the private sector. Currently, no offshore wind farms exist in the United States.

Estimates of wind availability and distribution are characterized by the level of annual average wind speed, water depth, distance from shore, and state administrative areas. The estimate in this report does not describe actual planned offshore wind development, and the report does not account for offshore areas that may be excluded from energy development on the basis of environmental, human use, or technical considerations.

The new database will be revised periodically to reflect better wind resource estimates and to include updated information from other datasets. It is intended to serve as the foundation for future modifications.

United States offshore wind resource at 90 meters (295 feet) above the surface.



Source: NREL National Wind Technology Center

NREL Identifies Significant Breakthrough in State-Space Hydrodynamic Modeling

Hydrodynamic models are central to the design of offshore wind turbines. Current models, though adequate for simulation, are totally inadequate for stability and modal analyses, or for controls design because of their formulation method.

NREL researchers developed a novel system-identification technique to identify hydrodynamic models in the state-space domain – a significant breakthrough. These state-space models offer immense capabilities previously unavailable, for example, modal and stability analyses, advanced controls design, faster simulations, and tight coupling of hydro state-space models with structural models. The new technique will also allow identification of hydrodynamic state-space models from tank tests or field-operations data. The concept, presented at the 2010 Ocean, Offshore and Arctic Engineering conference, received strong interest, particularly by maritime researchers, who see its impacts in terms of extended benefits and enormous computational time savings. In the immediate future, NREL plans to further develop this concept and demonstrate its application to a broad range of tests, including simulation, stability analysis, and controls design. The results will be presented at a number of high visibility conferences.

HC Sorensen, Middelgrunden Wind Turbine Cooperative/PIX17855

NREL researchers have developed a novel system-identification technique to identify hydrodynamic models in the state-space domain, a breakthrough for offshore wind turbine design.

Recent resource assessments by NREL have shown the considerable potential of offshore wind development. Of the contiguous 48 states, 28 have a coastal boundary. U.S. electric use data show that these same states use 78% of the nation's electricity (EIA 2006). For most coastal states, offshore wind resources are the only indigenous energy source capable of making a significant energy contribution. In many congested energy-constrained regions, offshore wind plants might be necessary to supplement growing demand and dwindling fossil supplies. This hydrodynamic state-space modeling development will be of great interest and aid toward the goal of developing the nation's huge offshore wind resource.

David Withrow (left) and Terry Boston (center), of PJM Interconnection, tour the National Wind Technology Center with Director, Fort Felker.

Robert Hawsey, NREL/PIX18219

NREL Engineers to Test Largest Turbine Yet

© Alstom/PIX18206

Under a Cooperative Research and Development Agreement (CRADA), NREL engineers will conduct field tests to International Electrotechnical Commission (IEC) standards on power quality, power performance, acoustic noise, and vibration that Alstom can use for certification. The research team will also continue a long-term fatigue loads study over several years.

Alstom, a global organization and wind turbine manufacturer, is building its first North American plant, a 115,000-square-foot wind power turbine assembly facility in Amarillo, Texas. NREL's testing of the Eco100 will provide Alstom with the reports it needs to meet IEC standards to certify the turbine and spur U.S. production.

NREL Science and Technology People in the News


Mike Linenberger, NREL/PIX14920

Helena Chum, a research fellow at NREL, was named a 2010 American Chemical Society (ACS) Fellow. Chum was recognized as a distinguished scientist who has demonstrated outstanding accomplishments in chemistry and made important contributions to ACS.


Karin Sinclair/PIX17427

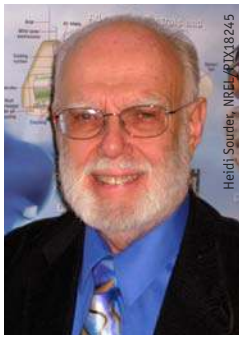
Trudy Forsyth, a senior engineer at the National Wind Technology Center, was recognized by the International Electrotechnical Commission (IEC) with the 2010 IEC 1906 Award.

Mike Himmel received the Charles D. Scott Award at the 32nd Symposium on Biotechnology for Fuels and Chemicals. Himmel is principal group manager of the Biomolecular Sciences Group at NREL and has served as principal investigator for DOE's Office of Energy Efficiency and Renewable Energy's Biomass Program since 1992.


Dennis Schroeder/PIX17800

Rommel Noufi has won the first-ever Distinguished Innovator Award, created by NREL to honor a single individual's long-term, sustained commitment to the laboratory. Noufi is a principal scientist in the National Center for Photovoltaics and has been a primary innovator in the area of copper indium gallium selenide (CIGS) photovoltaic solar cell technology.

Manuel Romero has been named a Hispanic Engineer National Achievement Awards Corporation (HENAAC) Annual Luminary by Great Minds in STEM (science, technology, engineering and mathematics). Romero is a senior scientist at NREL's Measurements and Characterization Division at the National Center for Photovoltaics.


Heidi Sourdes, NREL/PIX18245

Bob Thresher and Larry Flowers were each named 2010 Innovators in Wind Power by Windpower Engineering magazine. Thresher, pictured right, is an NREL Wind Energy Research Fellow and has 30 years of exemplary experience in the field. He served as director of the National Wind Technology Center (NWTC) from 1994 to 2008. Flowers is a principal project leader at the NWTC.

Paul Veers, who had a distinguished 30-year career including Wind Energy Technology Program Manager at Sandia National Laboratories, has joined the National Wind Technology Center at NREL as chief engineer.

John Wohlgemuth, formerly a senior scientist with BP Solar and project manager for that company's DOE-sponsored Technology Pathways Partnership Program, has joined NREL as a principal reliability physicist.


Patrick Corkery/PIX16761

Alex Zunger, a research fellow at NREL, was awarded two prestigious scientific honors by the University of Rome, Italy – the 2010 Tomassoni Physics Prize and the Science Medal of Scola Physica Romana. Zunger was selected for "his fundamental contributions to the development of the Quantum Theory of Real Solids."

Three NREL Scientists Lauded as Industry Pioneers

At the recent World Renewable Energy Congress/Network (WREN) in Abu Dhabi, three NREL researchers were named WREN Pioneers. Falah Hasoon, Chuck Kutscher, and David Renné were recognized for the impact their discoveries and innovations have made to the progress and acceptance of renewable energy technologies.


Dennis Schroeder/PIX17657

Chuck Kutscher is a principal engineer and manager of the Thermal Systems Group at NREL. He currently leads research on parabolic trough solar collector systems and the development of a design handbook on solar industrial process heat systems.


Warren Gretz/PIX04844

Falah Hasoon is a senior scientist at NREL. For more than 25 years, he has actively researched material growth and characterization of photovoltaic materials and device processing.

David Renné is a principal program manager with NREL's Resource Information and Forecasting Group. He develops and manages programs on renewable energy resource assessment and analysis, and the integration of resource data into geographic information systems.

Christensen is NREL's new Deputy Laboratory Director for S&T


ORNL/PIX18260

Dana C. Christensen became NREL's new Deputy Laboratory Director for Science & Technology on November 1. Christensen came to NREL from Oak Ridge National Laboratory (ORNL), where he served as the Associate Laboratory Director for Energy and Engineering Sciences. In his most recent role at ORNL, Christensen was responsible for more than $350 million in programs for a variety of government and industrial sponsors in all dimensions of energy science and technology including energy efficiency and renewable energy.

Prior to his tenure at ORNL, he was the Principal Associate Laboratory Director for Threat Reduction at Los Alamos National Laboratories. He has 27 years of management experience in materials science, fossil and renewable energy, and scientific research in support of the U.S. Department of Energy (DOE) and other government agencies.

He attended New Mexico State University, graduating with baccalaureate and doctoral degrees in chemical engineering, and attended the University of New Mexico, receiving an MBA. He is the author of numerous publications on the science and technology of plutonium chemical processing.

Corbus Named Laboratory Program Manager – Electricity Systems

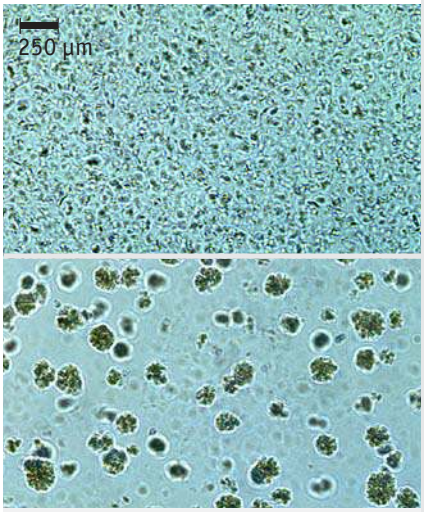

Kelly Wang, NREL/PIX18243

David Corbus was named NREL Laboratory Program Manager–Electricity Systems in mid-September, succeeding Richard (Dick) DeBlasio. Corbus will lead NREL activities funded by the Department of Energy's (DOE's) Office of Electricity Delivery and Energy Reliability (OE), providing program direction, technical leadership, and business management as well as program development for NREL's portfolio of projects funded by DOE-OE.

Corbus joined NREL in 1991 as an energy analyst, and after four years working in areas such as environmental analysis, transferred to the National Wind Technology Center (NWTC). At the NWTC, he tackled a range of activities including wind turbine research and international applications of renewable energy technologies. Corbus moved to the systems integration group in 2005, where he has focused on electrical grid operating impacts, transmission, and interconnection issues. This included working closely with regional grid operators, and he is the project manager for both the Eastern Wind and the Oahu Wind Integration and Transmission studies. He succeeds Sue Hock, who managed NREL's Smart Grid activities that were funded by DOE-OE in FY 2009-10. Corbus holds a master's degree in applied science/mechanical engineering and a bachelor of arts from New York University.

Transportation Team Breakthrough Paves Way for More Reliable Biodiesel

The stability of biodiesel, petroleum diesel, and blends of the two concerns NREL researchers not only at work but also at home. NREL Principal Engineer Bob McCormick has seen the neighborhood kids waiting for the school bus that never comes on very cold mornings in the Colorado foothills. Unlike some parents, he and his NREL team have the resources to understand the problem, and in the spring of 2010, the team made a research breakthrough.



Light microscope images showing the initial SMG crystals that form upon cooling (top) and the more stable, higher-melting-point crystals that form upon warming or holding at constant temperature (bottom).

It has long been known that diesel /biodiesel blends do not always perform well at very low temperatures and, more importantly, that predicting the temperature at which they exhibit reliable performance is difficult. McCormick and NREL Staff Chemist Gina Chupka set out to study the unpredictable nature of biodiesel crystallization – the condition that impedes the flow of the fuel in cold weather. The first components that crystallize at low temperatures cause the fuel to become visually clouded and the term "cloud point" is used to designate the temperature at which those crystals form. (Light passed through a sample of the fuel is scattered as it begins to crystallize and becomes cloudy.) However, cloud point has not been a reliable predictor of biodiesel's performance, and determining why was the overall goal of the research.

Chupka, who headed up the study, discovered that at certain concentration levels saturated monoglycerides (SMGs), a minor impurity in biodiesel, can crystallize and then begin to dissipate as the fuel warms, but upon continued warming, the SMGs recrystallize into a more stable crystalline form that ultimately melts at a much higher temperature. "This was a real breakthrough in our understanding of the cause of biodiesel low-temperature problems," explains McCormick, who has been working with the Fuels Performance Group in NREL's Center for Transportation Technologies and Systems for more than nine years.

The NREL team believes that the SMGs initially precipitate as a less stable or metastable polymorph – that over time or upon slow heating converts into a more stable, higher melting polymorph. Polymorphs of the same material have the same chemical composition but a different crystalline structure and thus will demonstrate different physical properties; they will have different melting points, solubility, and stability. According to McCormick, this discovery could lead to more dependable, cold-weather biodiesel. "We could improve the performance of biodiesel by limiting the amount of saturated monoglycerides," he says. It can also lead to different test methods and cloud point ratings for biodiesel, making its performance more predictable in the future.

NREL Solar Technologies Take Home Two R&D 100 Awards

Two innovative NREL solar technologies earned R&D 100 Awards in 2010. These prestigious awards – nicknamed the "Oscars of Invention" – honor the best new technologies from around the world as judged by the editors of *R&D 100 Magazine* and a jury of specialists in their respective fields. For their contributions to the development of a utility-scale power generator and their invention of an etching technique for silicon solar cells, researchers at the National Center for Photovoltaics (NCPV) earned NREL two places on this year's list, bringing the laboratory's total number of R&D 100 winners to 47.

> "These two technologies will play an important part in advancing solar energy's competitiveness and enhancing the availability of solar power in the United States and around the world."
>
> Dan Arvizu
> NREL Director

Amonix 7700 Solar Power Generator

The Amonix 7700 Solar Power Generator was developed in a partnership between NREL and Amonix, a leading producer of concentrating photovoltaic (PV) systems. This invention is a highly efficient bulk power generator that can produce 40% more energy than conventional fixed PV panels. It is the first terrestrial PV system capable of converting one-fourth of the sun's energy into usable electricity. The 52-kilowatt system was designed for utility-scale concentrator applications and is expected to sharply increase the opportunity for PV-generated electricity to reach grid parity with fossil fuels.

Courtesy of Rick Hurt, University of Las Vegas/PIX13465

The Amonix 7700 concentrates the energy of the sun to generate bulk power—producing "more power per tower" than any of its competitors.

"Black Silicon" Nanocatalytic Wet-Chemical Etch

Also honored was NREL's "Black Silicon" Nanocatalytic Wet-Chemical Etch. With this technology, NREL PV researchers have shown that silicon solar cells that are chemically etched to appear black can better absorb the sun's energy. The inexpensive, one-step antireflection technique allows silicon wafers to absorb 98% of solar radiation – a 3% gain over the conventional antireflection method. This development promises to reduce manufacturing production cost and capital expense, with the improvements resulting from NREL's invention potentially lowering the levelized cost of energy from a silicon PV array by about 2.5%.

Dennis Schroeder, NREL/PIX17850

NREL's wet-chemical etching technology demonstrates that "black silicon" solar cells can better absorb solar energy.

NREL Researchers Shine at Photovoltaic Specialists Conference

NREL's contributions to the photovoltaic (PV) industry were recognized at the 35th Annual Photovoltaic Specialists Conference, held earlier this year in Hawaii. Leading PV researchers from around the world participated in the conference's presentations, lectures, and tutorials on the latest advancements in the field. NREL attendees shared critical developments in their specialized areas of PV research and development, contributing 62 abstracts to the conference, all of which were accepted. Twenty-seven of these abstracts were selected for oral presentations – by far the most chosen from any single organization at the conference.

NREL Releases High-Impact Publications

NREL research resulted in several significant publications in the latter half of 2010. All of these publications are available on NREL's Web site.

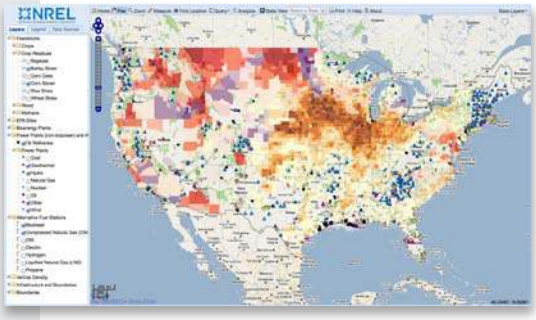
Advanced Vehicles and Fuels

- *"Environmental and Sustainability Factors Associated With Next-Generation Biofuels in the U.S.: What Do We Really Know?"* (journal article)

- *NREL's Hydrogen-Powered Bus Serves as Showcase for Advanced Vehicle Technologies* (PDF 885 KB) (tri-fold brochure)

Biomass

- *Algal Biofuels R&D at NREL* (PDF 918 KB) (fact sheet)
- *BioEnergy Atlas* (Web portal)
- *Novel Biomass Conversion Process Results in Commercial Joint Venture* (PDF 908 KB)



- *Novel System for Recalcitrance Screening Will Reduce Biofuels Production Costs* (PDF 904 KB)
- *Reducing Enzyme Costs Increases Market Potential of Biofuels* (PDF 982 KB)

Buildings

- *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (PDF 906 KB) (journal article)
- *Research Support Facility – A Model of Super Efficiency* (PDF 461 KB) (fact sheet)
- *Technical Support Document: Strategies for 50% Energy Savings in Large Office Buildings* (PDF 1.98 MB)

Energy Analysis

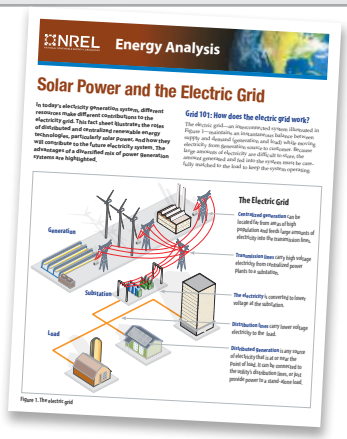
- *NREL Helps Apply Renewable Energy and Energy Efficiency Technologies Worldwide* (PDF 425 KB) (fact sheet)
- *Policymaker's Guide to Feed-in Tariff Policy Design* (PDF 2.1 MB)

Geothermal

- *Geothermal Policymakers' Guidebooks* (NREL Web subsite)
- *Geothermal Energy Production from Co-Produced and Geopressured Resources* (PDF 588 KB) (fact sheet)

Solar

- *Community Response to Concentrating Solar Power in the San Luis Valley* (PDF 1 MB)



- *Concentrating Solar Power, Best Practices Handbook for the Collection and Use of Solar Resource Data* (PDF 7.32 MB)
- *Solar Power and the Electric Grid, Energy Analysis* (PDF 767 KB) (fact sheet)
- *Solar Powering Your Community: A Guide for Local Governments, Solar Energy Technologies Program* (PDF 751 KB) (fact sheet)

Wind

- *2009 Wind Technologies Market Report* (PDF 2.98 MB)
- *Assessment of Offshore Wind Energy Resources for the United States* (PDF 9.59 MB)

- *Environment and Siting: Supporting Research on Impacts to Birds, Bats and Habitats from Wind Development* (PDF 580 KB) (fact sheet)
- *National Wind Technology Center – Wind Resource Assessments and Mapping* (PDF 580 KB)
- *Wind Energy Ordinances* (PDF 559 KB) (fact sheet)

Scientific Innovation Without Borders

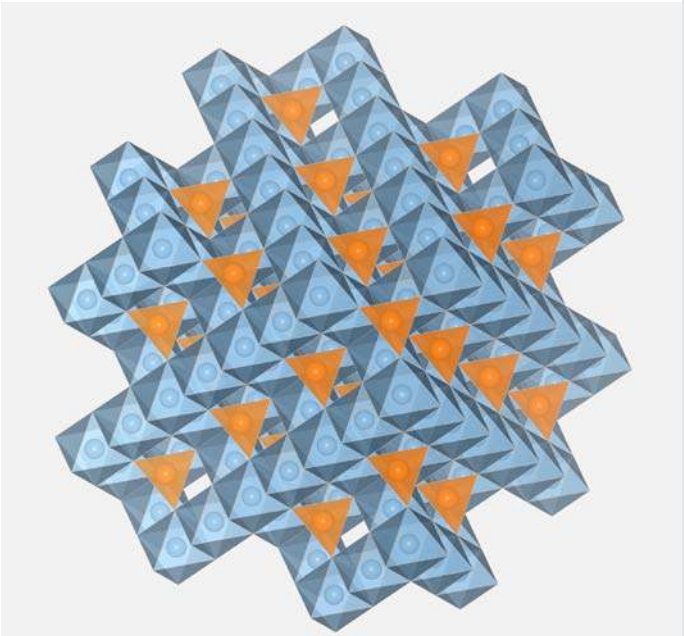
Theory probes the truth, while experiment tests the truth. Taking this concept to heart, scientists in the NREL-led Center for Inverse Design are addressing the crucial grand challenge of *materials by design* with an approach that integrates theoretical and experimental pursuits – essentially, innovation without borders.

The center's approach to materials science reverses the direction of the conventional paradigm to get the following: "Given the desired property of a material, find the structure of that material." Operationally, the center seeks to make significant progress with this approach by uniting theorists and experimentalists into a single band of allies.

Earlier this year, researchers within the center gathered at Northwestern University to review first-year accomplishments in four "entry-point" projects. Alex Zunger, director of the center, asked the researchers to provide "integrated experiment/theory presentations on each project, rather than two monologues." The resulting presentations reflected an impressive collaboration of theory and experiment – providing one story line, not two, on scientific advances in materials by design.

The first project focuses on so-called A_2BO_4 (or spinel) materials, which are p-type transparent conducting oxides (TCOs). The motivation for studying these materials is especially for greater design flexibility and higher efficiency of inorganic/organic solar cells, but also for their use in functional windows and transparent electronics. To many scientists, highly transparent conductive p-type TCOs are considered the "holy grail of TCOs."

Exemplifying this "borderless" approach, the review for this project wove together the results of seven presenters. Typically alternating a theorist and experimentalist, the presentation represented the work being conducted at three different institutions – Northwestern University, Stanford Synchrotron Research Laboratory, and NREL.



Visualizing one form of an A_2BO_4 spinel structure.

In the first section of the presentation, NREL scientists detailed work to identify regions of thermodynamic stability for desired material phases and which materials could be eliminated from further consideration for failing to have desired properties. A conclusion of this initial theoretical study was that self doping in cobalt zinc oxide spinel is not effective.

Scientists are addressing the crucial grand challenge of *materials by design* with an approach that integrates theoretical and experimental pursuits.

The next section focused on thin-film combinatorial exploration, with studies by experimentalists from NREL and Northwestern corroborating the theoretical conclusion that self-doping indeed does not work well. Instead, one must consider extrinsic dopants to produce suitable spinels.

The final section covered work by scientists involved in materials characterization, who described the fundamental properties of bulk materials. They concluded that a solid solution exists between Co_3O_4 and Co_2ZnO_4; furthermore, only zinc-poor compositions are stable at high temperature.

A similar approach, for study and presentation, is being followed within the other three "entry-point" projects. And the theoretical and experimental scientists in the Center for Inverse Design – at the partner institutions of NREL, Northwestern, Oregon State University, and Stanford – are confident that this "borderless" approach to operations will help lead to success in developing materials by design.

Energy Innovations is a publication of the National Renewable Energy Laboratory.

Managing editor: *Robert Hawsey*
Technical editors: *Terri Jones, Ernie Tucker*
Designer: *Mark Swisher*

Visit our Web site at www.nrel.gov

To subscribe to **Energy Innovations**, visit *www.nrel.gov/news/subscription*

If you have any comments or questions about this publication, please contact the NREL Public Affairs office at 303-275-4090.

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

National Renewable Energy Laboratory
1617 Cole Boulevard, Golden, Colorado 80401
303-275-3000 • www.nrel.gov

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

NREL/BR-2000-49077 • December 2010