

CLEAN ENERGY INNOVATION AT NREL

Continuum

PARTNERING: AN ENGINE FOR INNOVATION



DAN SAYS

PARTNERING: AN ENGINE FOR INNOVATION

Collaborative research truly is an engine for innovation. While the term "partnership" may seem straightforward, there are actually many ways in which the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) engages in research with the public and private sectors.

Some ways we partner include:

- ▶ Agreements with leading companies such as Toyota, which came to the lab to access cutting-edge electric vehicle technology, or Verizon, which sought the lab's expertise in designing photovoltaic cellular towers.
- ▶ Connections with NREL alumni who licensed a technology from the lab and use our expertise and facilities to pursue breakthroughs with us.
- ▶ Formation of hybrid agreements as in the case of NREL and HP. NREL set requirements, and then the lab and HP collaborated on the development of the Energy Systems Integration Facility's (ESIF) highly efficient high-performance computer, which HP has since launched as a new product offering.
- ▶ Assistance to government or nonprofit organizations, such as the California Energy Commission, which is leveraging NREL's deep knowledge in transportation to help meet emission reduction goals.
- ▶ NREL researchers or teams who innovate and find startup companies willing to back a novel idea.

Our newest tool is the Agreement for Commercializing Technology (ACT)—a pilot program launched by DOE that gives labs and their partners more flexibility in crafting agreements. NREL and the Wells Fargo Foundation are partnering under ACT to provide buildings related technologies to Wells as part of a \$10 million, five-year agreement. This partnership will also enable the Wells Fargo Foundation, through its Innovation Incubator (IN²) program, to provide funding and support to innovative renewable energy and efficiency startup companies.

In the past year, NREL had more than 650 active agreements with entities beyond DOE, including industry, government, academia, small businesses, and international and nonprofit organizations. The lab also signed more than 245 new agreements to partner with federal agencies and non-federal entities.

Of course, NREL benefits in many ways from engagements with public and private entities. We assess market needs and trends, and get direct feedback about problems and opportunities, helping inform our research agenda. This close connection to the marketplace enables us to ensure that our research is relevant and that the insights and technologies we develop can be more easily adopted and commercialized.

This issue of *Continuum* highlights the many ways NREL partners with private industry and other research institutions. You will find references to many of the partnerships I've mentioned and examples of the scope of our engagement with industry leaders, government organizations, and startups.

We are proud of our partnerships—and the impact they are having on our mission to be DOE's innovation engine for renewable energy and energy efficiency technologies.

Dr. Dan E. Arvizu, Laboratory Director



Photo by Dennis Schroeder, NREL

Contents

FALL 2014

02

CONNECTING TECH TO MARKET IN NEW WAYS

NREL has found the means to reach its goal of growing long-lasting relationships that bring scientific innovation to market.

09

FROM THE START: NREL NURTURES A GROWING WIND INDUSTRY

The National Wind Technology Center grew from a site for testing small turbines into the nation's premier research facility for wind energy technologies, helping the wind industry grow with it.

> 14

NREL'S NEWEST PARTNERSHIP TOOL INCREASES FLEXIBILITY

The Wells Fargo Foundation and NREL are unveiling a novel \$10 million, five-year agreement at NREL's annual Industry Growth Forum, taking the next step in a growing collaboration.

> 16

FINDING NEW WAYS TO FOSTER CLEAN ENERGY PARTNERSHIPS

With expanding Department of Energy (DOE) support and enhanced business agility, NREL is better positioned than ever before to help move big ideas to market.

> 18

INDUSTRY GROWTH FORUM CULTIVATES CLEAN ENERGY ENTREPRENEURSHIP

NREL's Industry Growth Forum brings together clean energy entrepreneurs and investors to facilitate the movement of innovation into the marketplace.

> 22

HELPING FORT CARSON MEET DOD ENERGY GOALS

NREL's diverse projects with the Department of Defense (DOD) at Fort Carson guide energy improvements that are moving the Army toward its visionary energy goals.

> 24

IMPACTING INNOVATION AND COMMERCIALIZATION: NREL'S PARTNERING FACILITIES

The award-winning Energy Systems Integration Facility is the latest addition to NREL's partnering sites.

> 26

R&D 100 AWARDS DEMONSTRATE CLEAN ENERGY LEGACY

NREL has won 57 R&D 100 Awards since 1982, many of which led directly to industry successes today.

Photo by Dennis Schroeder, NREL

CONNECTING TECH TO MARKET IN NEW WAYS

NREL has found the means to reach its goal of growing long-lasting relationships that bring scientific innovation to market.

Partnerships established by NREL take many forms. Each is unique. Yet, whether working with a photovoltaic startup or a major automaker, NREL has found the means to reach its goal of growing multiple, long-lasting relationships that bring scientific innovation to market.

The lab and its researchers have forged strong bonds with the likes of the California Energy Commission, General Motors, Toyota, Verizon, and federal agencies.

There are currently approximately 650 active partnership agreements with entities other than the U.S. Department of Energy (DOE). And while circumstances differ according to partners' business needs, some points show up consistently.

"There's a foundational element to the relationship that needs to be established right up front, often through multiple visits and meetings," said Ron Schoon of NREL's Commercial Partnerships office, which seeks to put a more strategic focus on significant partnerships with industry. Additionally, when the lab has an aligned vision with a partner, they find ways to mutually support one another for the common good. Underlying everything is an open-for-business

approach, which may be the laboratory's secret advantage. Because NREL is an applied research lab, it is deeply rooted in energy efficiency and renewable energy technologies, and connecting to that market space is part of the lab's DNA.

"What separates us [from other DOE labs] is we do what we call 'mission-oriented tech transfer.' Little research is done that is not oriented toward market solutions and creating





Photo by Dennis Schroeder, NREL

NREL engineers Mike Simpson and Tony Markel plug in a Toyota plug-in hybrid electric vehicle as they run a test at the Energy Systems Integration Facility.



new energy-related technologies," said Bill Farris, NREL's associate laboratory director for Innovation, Partnering, and Outreach. "Our job's only done when an innovation is in wide use in the market, and positively impacting society."

In a sense, the lab not only "grows" innovations, it readies them for harvest in the market. And it does so cooperatively. The lab has more cooperative research and development agreements (CRADAs) than any other DOE lab—even ones five times its size.

"Our job's only done when an innovation is in wide use in the market, and positively impacting society."



NREL scientist Huyen Dinh and General Motors partners Paul Yu, Eric Bonn, and Balsu Lakshmanan look at the instruments in the Fuel Cell Development and Test Lab at the ESIF. GM and NREL are working together in a CRADA.

Photo by Dennis Schroeder, NREL

CRADAs allow the lab and partners to perform collaborative research while protecting a company's and NREL's existing intellectual property. This establishes a foundation for commercializing the results of the interaction, fostering a collaborative process.

But CRADAs don't just spring up. Seeds have to be planted, at times across an entire industry, as occurred in 1993 when the Partnership for a New Generation of Vehicles—which included NREL—was launched to speed hybrid-electric car development. That helped jumpstart decades of NREL research into alternative fuel vehicles as well as powertrains, batteries, and other components.

THE PATH TO PARTNERSHIPS IS FERTILE GROUND

NREL and Toyota offer a good example of two partners working together to cultivate a robust relationship across a broad area. The kernels of the current engagements were sown years ago, and nurtured through meetings and industrywide discussions as they aligned their visions on clean transportation to benefit society.

DID YOU KNOW?



In 2010 Tony Markel, a principal investigator in NREL's Transportation & Hydrogen Systems Center, was seeking partners to participate in vehicle-to-grid (V2G) research, a concept where plug-in electric vehicles communicate with the power grid. Markel found a collaborator at the Toyota Research Institute-North America in Ann Arbor, Michigan, and they established common ground while working together on a project in Boulder, Colorado—led by University of Colorado and Xcel Energy—evaluating the performance of prototype plug-in hybrid vehicles. In 2011, NREL and Toyota fashioned a technical services agreement (TSA) and worked together for a year on initial V2G research for Toyota.

As Markel and others tended it, the Toyota-NREL partnership started to sprout. Schoon joined in the meetings, listening to Toyota's needs and learning of significant interest in other transportation research at the lab beyond the V2G technologies. In 2011, Toyota's chairman of North American operations and other top executives stopped by NREL on a visit to Denver, helping lay a foundation that now includes regular executive visits to the lab from different parts of the Toyota organization.

Today, NREL's V2G work with Toyota has blossomed into a CRADA that includes a couple dozen vehicles being tested in the Energy Systems Integration Facility (ESIF) and several modifications to increase and extend the scope of the research. Currently, the breadth of the NREL-Toyota collaboration spans the sustainable transportation portfolio, involving numerous NREL research centers and groups within Toyota, both in North America and Japan. Multiple agreements exist between the lab and Toyota resulting in, among other things, advanced hydrogen fuel cell cars loaned to the lab for testing, biofuels research in the Integrated Biorefinery Research Facility, and a grid storage study.

As the bond deepened, reciprocity emerged. In 2012, when Toyota hosted its annual Future Mobility Seminar in Denver, the educational gathering was supported by the lab and included special NREL tours. Likewise, when NREL dedicated the ESIF in 2013, a Toyota vice-president was on hand to speak. These types of examples have grown out of this foundation and alignment.

"We see our partnership with NREL as an excellent example of public-private partnerships, where everyone benefits. We are proud of this partnership," said John Hanson, a Toyota spokesman.

And such collaboration helps nourish the industry, not just a single company. In June 2014, General Motors (GM) and NREL announced a CRADA to reduce automotive fuel cell stack costs using ESIF, building on a relationship dating back to 1993. GM is also collaborating with Honda on next-generation fuel cell and hydrogen storage systems.

In the past year, NREL had more than 650 active agreements with entities beyond DOE including industry, government, academia, small businesses, international organizations, and nonprofits to advance the use of clean energy technologies in the marketplace. The lab also developed (or signed) more than 240 new agreements to partner with federal agencies and non-federal entities in fiscal year 2014. These new agreements generated more than \$58 million in new partnership agreement value.



Meet NREL innovator Bill Farris and learn how his work contributes to a cleaner energy future by visiting http://www.nrel.gov/continuum/partnering/tech_to_market.html



PARTNERSHIPS SPURRED BEYOND INDUSTRY

Naturally, not all relationships involve one other single organization. In those cases, a different approach is needed. For example, NREL was the lead for the National Advanced Biofuels Consortium (NABC), established in 2010 to develop biomass-based alternative fuels that can be "drop-in" replacements for gasoline and diesel fuel. Funded by DOE, the NABC was comprised of 17 partners from national labs, universities, and industry, including small companies. The goal: get one or more advanced biofuel to a pilot-ready state.

"It was hugely successful. We were able to identify common areas of interests of organizations," said Tom Foust, director of the National Bioenergy Center. By the time they finished in December, 2013, "we exceeded the goal and were able to take two technologies to a pilot-ready state." Those two startups, Amyris and Virent, Inc., emerged to compete in the marketplace.

"We did achieve our goals of moving the technology forward," Foust said, but in addition, NREL continues to work with the companies as they improve their concepts. "We also formed ongoing partnerships."

Likewise, NREL has worked with the California Energy Commission (CEC) the state's primary energy policy and planning agency, as well as the South Coast Air Quality Management District (SCAQMD), the smog control agency for all or portions of Los Angeles, Orange, Riverside, and San Bernardino counties, for more than a decade, but the relationships flourished in 2011. That's when NREL led a project with CEC, SCAQMD, and DOE to invest up to \$11.4 million to support the development of natural gas engines and vehicles. Companies selected for awards invested nearly \$3.7 million in additional funds to support \$15 million in total projects.

"A core responsibility of the CEC is to research and deploy vehicle technologies and low-carbon alternative fuels that can help meet the state's climate change policies and provide air quality and cost benefits," said Robert Weisenmiller, chair of the CEC. "Our partnership with NREL furthers that vision of a clean-energy future."

The strong partnership between NREL, the CEC, and SCAQMD was instrumental in the final development and demonstration of the Cummins Westport, Inc., ISX 12 G, an advanced 12-liter natural gas engine capable of achieving ultra-low emissions. The ISX 12 G went into commercial production in 2013 with strong demand in the Class 8 heavy-duty truck market.

"NREL was able to find common partners, see what the needs were, and figure out where our goals overlapped," said NREL Project Manager Margo Melendez. "This partnership was bigger than the sum of its parts."

During the four-year project, NREL has overseen the natural gas engine and vehicle research, development, and demonstration projects to develop highly efficient natural gas engines that meet or exceed 2010 emission standards; integrate natural gas engines into different chassis and vehicle platforms; and verify fuel efficiency, petroleum reduction, and emissions benefits in real-world operation. A couple of years into the project, CEC tapped NREL for additional support, including an update to its Natural Gas Vehicle Research Roadmap.

The strong connection shows, in Melendez's words, that the CEC and SCAQMD "trust us and look to us for advice—partly because we are an unbiased third party—but also because we have a broad reach with stakeholders and have expertise ranging from engineering and environmental research to analysis. This really positions us all as partners."

READY TO PARTNER WITH SMALL OR LARGE BUSINESSES

Sometimes the path to partnership gets a push from chance that adds momentum to hard work. Once in a while, as NREL scientist David Young learned, unforeseen connections happen more than once on the same project.

Young, along with researcher Brian Egaas, had been working since 2003 on a concept of using LEDs to assess the quality of solar cells. "One day, colleague Pauls Stradins happened through the lab and made a brilliant suggestion" which changed the course of the project, Young said.

The trio patented their idea and Young built a prototype of the Real-time QE, complete with taped-together pieces. The device was able to take measurements which had required 20 minutes and do them in only one second. "It opened up new possibilities for this technique."

Then came a second break. "I was walking down the hallway, and a colleague stopped me and said there were three visitors here looking for new ideas to commercialize," Young said. He walked in, gave his 10-minute spiel, and the group from Tau Science Corp. immediately wanted to license the technology. The technology, which also garnered a 2011 R&D 100 Award for being among the year's most significant inventions, is now sold as the FlashQE. The lesson for Young is that "being connected to a lot of people so they can see what you're working on, and building friendships, is important."

In the professional sense, that tenet holds true in NREL's partnership with Verizon. The phone carrier was looking for better ways to power its off-grid sites and save on fuel and delivery costs while also improving reliability. "We looked at a number of technical assistance options, but none offered the third-party, nonbiased analysis that NREL has perfected," said Roger Maiorano, principal engineer at Verizon. "NREL's expertise, labs, facilities, research, and software tools made the partnership a great fit."



Photo by Dennis Schroeder, NREL

"We did achieve our goals of moving the technology forward," Foust said, but in addition, NREL continues to work with the companies as they improve their concepts. "We also formed on-going partnerships."

NREL Principal Engineer Andy Walker works closely with many partners, including Verizon, to deploy commercially available energy efficiency and renewable technologies.

NREL's Andy Walker and Maiorano worked hand-in-hand under a TSA beginning in 2012 and continuing to date, to determine the viability of a number of renewable energy projects. The lab's analysis has shown Verizon could reduce the cost of powering its remote sites by 45% or more by using solar photovoltaics, wind turbines, and additional batteries. "There's a definite trust in NREL's expertise," Maiorano said. The partners are also expected to finalize two more TSAs in 2014.

Clearly, across multiple industries, NREL has found the way to seed partnerships with companies and organizations, resulting in sustainable harvests for the marketplace.

—Written by Ernie Tucker



Four large utility-scale wind turbines and two smaller research turbines are the visual centerpiece of today's National Wind Technology Center near Boulder, Colorado.

Photo by Dennis Schroeder, NREL

FROM THE START: NREL NURTURES A GROWING WIND INDUSTRY

The National Wind Technology Center grew from a site for testing small turbines into the nation's premier research facility for wind energy technologies, helping the wind industry grow with it.

On the plains south of Boulder, Colorado, nestled against the foothills, is the 305-acre National Wind Technology Center (NWTC), the nation's premier research facility for wind energy technologies. The NWTC is a satellite campus of NREL and is located about 25 miles north of NREL's main campus. It hosts four megawatt-scale wind turbines, two 600-kilowatt research turbines, and an assortment of small wind turbines. Its world-class structural testing laboratory and dynamometer test facilities draw wind turbine manufacturers from around the world.

But this impressive site grew from much humbler beginnings, in the days before a true utility-scale wind turbine market existed. NREL's efforts grew alongside the wind power industry, first with testing capabilities and then with engineering solutions to many of the fledgling industry's biggest technical problems. In some ways, NREL is the Johnny Appleseed of wind turbine technology: the lab planted the seeds of engineering and testing, and years later, wind turbines began sprouting up all over the country. Yet today's blossoming industry was a distant vision in the late 1970s.

The Early Days

Shortly after NREL began operating as the Solar Energy Research Institute (SERI) in 1977, the current location of the NWTC became the site of a test facility for small wind turbines—the kind a homeowner, small business, ranch, or farm might use. Rockwell International originally operated the site, but SERI took over in 1984, testing the performance of new small wind turbines to assure potential buyers that the turbines function well.



"That role is still going on," said NREL Wind Energy Research Fellow Robert Thresher. "There are two small turbines under test right now, and we've tested eight to 10 turbines over the past three to five years."

Back when SERI started operating the wind test site in 1984, the utility-scale wind industry was in its very early years. Strong incentives in California were driving the installation of wind power facilities there—some 10,000 wind turbines were installed between 1981 and 1985—but the turbine designs of that era were prone to failure. To address that issue, the U.S. Department of Energy (DOE) funded the Cooperative Field Test Program, under which SERI researchers headed into the field to work with industry to improve the performance and reliability of their turbines.

"We worked with industry, and we ran tests on raising the turbines higher off the ground, looked at wind wakes, and did all kinds of research in the field," said Thresher. "That was really our first big cooperative program with the industry."

Developing World-Class Testing Facilities

NREL's involvement with the wind power industry grew by leaps and bounds in the late 1980s and throughout the 1990s, and the laboratory developed unique testing capabilities along the way. With blade failures common in the field, the wind industry developed a standard practice for all wind turbine blades to be full-scale tested before they were deployed commercially. As a result, one of NREL's top priorities was to build a mechanical testing facility for wind turbine blades. Blade testing began in 1989 and the facility—now called the Structural Testing

Laboratory—has tested more than 100 wind turbine blades to the breaking point in the past quarter century.

Wind blade testing also led to a research agreement with Kenetech Windpower, Inc., then the U.S. leader in the wind power industry. Industry needs also led NREL to build a dynamometer to test turbine drivetrains. The dynamometer is essentially a big motor that simulates the loads that the spinning rotor places on the drivetrain, including "off-axis" loads that come from gusty winds.

"The industry was saying they needed a way to test their drivetrains to put forces on the machinery before they deployed them in the field," said NREL Principal Engineer Walt Musial. "Based on this input from industry, the 2.5-megawatt dynamometer was built and commissioned in 1999. It was the first of its kind: there were lots of dynamometers out there, but they couldn't test a wind turbine at the same power levels and torque levels that we needed. So we built one that was unique, and it's been busy ever since.

"A lot of the gearbox manufacturers had ways to test their gearboxes, but we were testing not just the gearbox but the whole drivetrain, and running it through conditions that resembled what it would actually see in the field. We could make sure that all the systems were operating exactly as they were designed before they got deployed in the field, so we cut down on the number of field failures that happened at the early parts of installations.

"We didn't really know how valuable it would be as a shakeout of the full design until we got it going, and then we realized that we couldn't test a gearbox until we got all the other stuff to work."



DID YOU KNOW?

NREL has been an international leader in offshore wind energy research for more than a decade. NREL's offshore wind turbine research capabilities focus on critical areas that reflect the long-term needs of the industry and DOE. Our researchers are perpetually exploring new wind and water power concepts, materials, and components as well as how those innovations perform and affect the energy system as a whole.

Meet NREL innovator Walt Musial and learn how his work in offshore wind energy research contributes to a cleaner energy future by visiting <http://www.nrel.gov/continuum/partnering/wind.html>



Photo by Dennis Schröder, NREL

NREL's newest dynamometer is capable of testing wind turbines up to 5 megawatts in capacity. The device exposes the wind turbine's drivetrain and generator—housed in the white nacelle on the left—to the loads and torques that they may experience in the field.

Getting Involved on the Design Side

While NREL got heavily involved in the testing of wind turbines and blades, it also started working on the design end. Early wind turbine blades were adapted from helicopters, but NREL researchers decided to apply their aerodynamics expertise, designing a more aerodynamic blade that would better handle the roughness caused by dirt and bugs accumulating on the blades. The result was three families of turbine blade airfoils—cross-sections of the blades from the root of the blade to the tip—that licensees could use to design and build their own turbine blades. Not only did these airfoils solve the roughness problem, but once mounted on a hub to form a complete rotor—the spinning, external part of the wind turbine—they also captured about 40% more energy. The blades also changed the way the wind industry thought about airfoils.

"NREL SHOWED THE INDUSTRY THE PROPERTIES THAT WERE NECESSARY FOR A WIND TURBINE AIRFOIL ... WE CREATED THE WHOLE CONCEPT THAT WIND TURBINES NEEDED DIFFERENT AIRFOILS, AND ROTOR DESIGNS HAD TO BE DIFFERENT THAN FOR AN AIRPLANE."



"NREL showed the industry the properties that were necessary for a wind turbine airfoil," said Musial. "We created the whole concept that wind turbines needed different airfoils, and rotor designs had to be different than for an airplane. So we developed the capability here—and this is before the current computer technology was available—to design, test, and build these new wind turbine rotors, which produced about 40% more energy than the ones built in the 1980s."

While working on airfoils, NREL was also leading efforts to improve wind turbine design as a whole. In 1990, DOE initiated the Advanced Wind Turbine Program to assist

The program's immediate goal was to make the turbines more resilient to the loads and buffeting caused by the wind, ultimately lowering the cost of wind energy. The program explored such concepts as variable-speed wind turbines, which could adjust their speed with the wind to capture more energy; rotors that could adjust the pitch of their blades to optimize wind energy capture; and turbines that actively pointed into the wind rather than passively turning downwind like a pinwheel. NREL worked directly with the wind turbine companies to review and analyze their design concepts and to test their prototypes.

Photo by Dennis Schroeder, NREL



The NWTC hosts four megawatt-scale wind turbines, two 600-kilowatt research turbines, and an assortment of small turbines.

industry in incorporating advanced technology into its wind turbine designs. The NREL-led program started by studying three existing wind turbines and examining ways to improve their performance, using such approaches as larger rotors, integrated drivetrains, better braking systems, and more aerodynamic blades that used NREL airfoils.

"NREL's involvement in these advanced turbine designs ensured that best engineering practices were being followed that would lead to certification," said NREL's Brian Smith.

One result of this program was the Zond Z40, developed by Zond Energy Systems, which had a 550-kilowatt generating capacity and was a three-bladed turbine that pointed into the wind. Although Zond is no longer in business, its technology was passed along through several companies, and the essential DNA of the Zond Z40 can now be found in General Electric's (GE) 1.5-megawatt wind turbine. This wind turbine has dominated the U.S. market for years and remains GE's top seller, with more than 16,500 units installed globally, making it the most widely deployed wind turbine in the world.

NREL also stepped up its Johnny Appleseed role for the wind industry, providing technical support to a project that literally scattered wind power plants across the country: the Utility Wind Turbine Verification Program. A collaboration between DOE and the Electric Power Research Institute—the utility industry's research organization—the program encouraged wind installations in locations other than California. It ultimately resulted in the first wind farms built in Iowa, Nebraska, Texas, and Vermont. Today, 39 states and Puerto Rico are home to utility-scale wind projects, and Texas now has more wind power capacity than California—more than twice as much!



Recent Years and Looking Ahead

With the wind power industry now booming, it is also maturing. NREL's involvement has changed in many ways, while remaining the same in others. NREL still carries out mechanical tests of wind turbine blades and drivetrains, as well as performance tests of small wind turbines. NREL also works directly with manufacturers of both small- and utility-scale wind turbines to improve their technologies. In fact, Siemens, Gamesa, and Alstom

have installed megawatt-scale wind turbines at the NWTC under cooperative research and development agreements (CRADAs) with NREL. A GE 1.5-megawatt turbine is also installed at the NWTC for research and development.

But as the needs of the wind power industry have evolved, so has NREL's research focus. NREL is now examining advanced wind monitoring and control schemes for individual wind turbines and for entire wind farms. While wind turbines currently rely on anemometers to measure wind speed, new laser-based systems can "see" wind gusts coming and help the wind turbine control system to adjust operation in anticipation of the coming winds. The result is better energy capture with lower loads on the turbine.

Meanwhile, NREL is applying fluid dynamics and supercomputers to understand how the wind moves through an entire wind farm. This work may inform wind farm layouts and operations, as upwind turbines may need to point slightly away from the wind to avoid detrimental wakes hitting the downwind turbines.

The industry also continues to face some of the same challenges it has always dealt with, including gearbox failures. To help industry address this challenge, NREL initiated in 2007 the Gearbox Reliability Collaborative (GRC), which consists of wind turbine manufacturers, project owners, researchers, and consultants. In its first five years, the GRC produced a new and improved gearbox design that incorporates advanced technology that increases the reliability of wind turbine gearboxes.

As its Johnny Appleseed role continues, NREL is hoping to plant the seeds for wind turbines to sprout in an entirely new location: the ocean.

"To do so, over the past 10 years we've aggressively partnered with European research laboratories; the groups that are developing offshore wind projects, including all of the DOE-sponsored offshore wind demonstration projects; the regulators who are permitting those projects; and in the future, we hope to be partnering with the projects that are being developed with private money," said Musial.

Ultimately, NREL hopes to extend the wind industry into the deep ocean, where floating wind turbines are needed.

"For our vision, which would involve hundreds of offshore wind farms in the United States, we'll need to not only deploy wind turbines in shallow water, but also develop technology for deeper water as well," said Musial.

—Written by Kevin Eber

NREL'S NEWEST PARTNERSHIP TOOL INCREASES FLEXIBILITY

THE WELLS FARGO FOUNDATION AND NREL ARE UNVEILING A NOVEL \$10 MILLION, FIVE-YEAR AGREEMENT AT NREL'S ANNUAL INDUSTRY GROWTH FORUM, TAKING THE NEXT STEP IN A GROWING COLLABORATION.

NREL's annual Industry Growth Forum (IGF), now in its 20th year, is the nation's premier clean energy investment forum. As such, it is the ideal venue to highlight a novel \$10 million, five-year agreement between NREL and the Wells Fargo Foundation. Wells Fargo has supported the IGF for years as part of a growing collaboration with the lab—and the company is taking the next step with the agreement using the lab's newest and most flexible partnership tool.

Wells Fargo became interested in establishing a formal partnership with NREL to take advantage of the lab's experience in working with startup companies and evaluating technologies. The built environment is a key area for Wells Fargo, one of the world's largest financial institutions with nearly 100 million square feet of real estate globally.

"We wanted to engage in a collaborative way as we're looking to position ourselves as a leader in innovation, and that's why we came to NREL," said Wells Fargo Business Initiatives Manager for Environmental Affairs Ashley Grosh. "To leverage the lab's expertise is an exciting opportunity for us."

Now, under a pilot agreement type known as an Agreement for Commercializing Technology (ACT) signed earlier in 2014, NREL and other U.S. Department of Energy (DOE) national laboratories will supply technical services to Wells Fargo through the new Innovation Incubator (IN²).

"Wells Fargo was looking for ways to partner with the lab," said NREL's Innovation and Entrepreneurship Center Director Richard Adams. "Collectively, we hit upon the idea—a program working with NREL's buildings researchers."

The new agreement offers a unique path toward fulfilling that goal by reducing the building footprint and managing energy use and costs. "IN² is designed to provide a framework for evaluating technologies and helping companies with business-related assistance," said Anne Miller of NREL's Technology Transfer Office, adding that it was a win-win for both partners.

And the partnership is clearly a great fit. "Wells Fargo is focused on innovation and finding ways to collaborate with key community partners and stakeholders. That translates into supporting the development of clean energy technologies, and specifically the building sector," Grosh said. Potential impacts reach beyond Wells Fargo as well. "If a technology works for us, it is likely going to work for our customers. It's going to have that trickle-down effect," she said.

THE INS AND OUTS

The IN² is designed to help support clean energy buildings-related technologies and startup companies overcome market gaps by providing access to both technical assistance and business development resources. The platform provides an opportunity for strategic partnerships. The effort will also help support small businesses, another desired outcome.

The opportunity for collaboration was created because of ACT's flexibility. And while the Wells Fargo ACT is not NREL's first—others have been signed—it exemplifies a partnership where flexibility in contracting enabled a program to go forward which could significantly augment the development and deployment of new technologies.

"If we put sustainable technologies in business, what type of impact could Wells Fargo and NREL have doing that?" Adams asked. The goal is to move technology along the commercialization path, to see it tested, and then deployed.

IN² is designed to support clean energy technologies and startups at various stages of development, including:

- ▶ Tier I: Lab Bench Scale
- ▶ Tier II: Prototype
- ▶ Tier III: Commercially Ready

The first year will be considered a pilot year as the NREL team works on establishing a process under the ACT, as well as how to assess different levels of technology





Richard Adams and Bill Livingood of NREL and Ashley Grosh of Wells Fargo discuss the impact of the new partnership at the NREL Energy Systems Integration Facility.

for market readiness. An independent advisory board made up of clean energy industry experts will select companies to be included in the IN² program after the companies have been scored by technical experts. The group will focus on five to 10 companies, ranging from Tier I to III stages, and make awards of \$50,000 to \$250,000 per company.

IN² will partner with NREL's buildings technology experts, who have validated technologies and strategies on behalf of agencies such as the GSA and the New York State Energy Research and Development Authority, and utilize their comprehensive suite of tools to analyze the most appropriate technologies for the program.

"Wells Fargo's investment in the energy efficiency sector is timely and noteworthy," said Bill Livingood with NREL's Buildings & Thermal Systems Center. "Their systematic approach to maximize the impact of their investments, which leverages NREL's deep knowledge in the buildings area, will be game changing."

Why ACT Now?

ACT was created to address requests by industry for flexibility in partnership agreement terms beyond what is available under DOE's cooperative research and development agreement (CRADA) or Work-For-Others (WFO) agreement. ACT is aligned with industry practice in areas such as intellectual property rights, indemnification, and payment issues. Also, while WFO arrangements and CRADAs tend to be tailored for two-party agreements between one company and a lab, an ACT "will make it easier to develop a multi-party research and development partnership," Miller said.

In addition, these new agreements also benefit the lab.

"LIKE ALL PARTNERSHIPS, WE LEARN FROM THIS," MILLER SAID. "IT KEEPS US RELEVANT TO INDUSTRY, AND HELPS US UNDERSTAND THEIR NEEDS BETTER."

However, as Adams noted, "business relations at this level are multilayered." And while having access to ACT or other new approaches is nice, they still "require a lot of effort to be successful."

—Written by Ernie Tucker

FINDING NEW WAYS TO FOSTER

CLEAN ENERGY PARTNERSHIPS

With expanding DOE support and enhanced business agility, NREL is better positioned than ever before to help move big ideas to market.

A U.S. Department of Energy (DOE) initiative unveiled in summer 2014 has the potential to strengthen NREL's stellar record in the technology transfer arena, positioning the lab to multiply the societal and economic impacts of its leading-edge clean energy innovations.

Launched by DOE Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) David Danielson during a visit to NREL in July 2014, the EERE Lab Impact Initiative aims to increase the market impact of the research conducted at DOE's national laboratories by doubling the intensity of successful lab-industry engagement over the next three years. The initiative is part of DOE's drive to deliver on President Obama's 2013 directive to accelerate the transfer of federally funded research and innovations to the private sector.

Danielson introduced a variety of proposed concepts and pilot programs that signal DOE's intent to expand its support of "tech-to-market" activities among its network of national laboratories, including:

- ▶ Allocation of 1% of EERE's annual \$800 million laboratory support to a fund that will advance new technology transfer efforts, focusing on big ideas
- ▶ A \$10 million to \$20 million "Small Business Voucher Program" to encourage labs to assist small businesses' commercialization efforts
- ▶ A \$2 million "Lab-Corps" pilot program to empower lab teams to identify market applications and create business models for commercializing high-impact technologies
- ▶ A national lab "Technologist-in-Residence" program featuring laboratory-industry exchanges of "embedded" researchers.

Such programs will allow NREL to augment its robust slate of technology transfer achievements. Many of these achievements stem from internal process improvements that have enhanced NREL's ability to bridge the gap between scientific discovery and market adoption.

INCREASING THE SPEED AND SCALE OF COMMERCIALIZATION AND DEPLOYMENT

For NREL, developing clean energy technologies is only the beginning. Building on its 37-year history of demonstrated innovation and achievement, the laboratory is pursuing its vision for a clean and sustainable energy future by not only delivering market-relevant innovations but also increasing the speed and scale of their commercialization and deployment.

"NREL is uniquely situated to partner to get technologies to market because of the agility, impact, and creativity found in our science and technology organizations and our partnering approaches," said Associate Laboratory Director Bill Farris.

These are not attributes NREL stumbled upon by accident. Viewing their development as mission-critical, the lab has made a concerted, organization-wide effort to address industry's demands, including speed, rapid capital growth, flexibility, innovation, and sustainable competitive advantages.

EXCEEDING GOALS AND BUILDING MOMENTUM

In 2009, NREL set a year five-year goal of tripling its innovations—a goal it surpassed in just three years. Driven to parlay that achievement to advance the nation's clean energy goals, NREL's Technology Transfer Office (TTO) sought to shorten the path by which NREL-developed technologies move from the laboratory to the marketplace. By focusing on streamlining the patenting, licensing, and partnering processes, TTO was able to reduce the time it takes to establish a partnership agreement with a company interested in commercializing an NREL innovation to about 60 days, positioning the laboratory as a leader in transferring technologies to the marketplace.

"The technology transfer momentum continues to accelerate as NREL scientists and engineers apply their breakthroughs to further our gains in energy systems integration and industry-changing energy solutions," said TTO Director Kristin Gray.

At NREL's 2014 Innovation and Technology Transfer Awards in May, Associate General Counsel for Intellectual Property



While touring NREL's National Wind Technology Center (NWTC) with NREL Director Dan Arvizu and NWTC Director Fort Felker in July, U.S. Department of Energy Assistant Secretary David Danielson discussed the importance of working with industry partners to enhance the integration of wind into our nation's energy mix.



Photo by Pat Corkery, NREL

John Stolpa noted that the lab filed more than 60 new patent applications and had 16 issued in 2013. The patent trends are pointing upward: the previous year there were 10 U.S. patents issued, and there were 43 issued in fiscal year 2014.

On the partnering side, the numbers are equally impressive. NREL is a standout among national laboratories with 166 active cooperative research and development agreements (CRADAs)—representing a quarter of all the CRADAs in the DOE system. And, in fiscal year 2014 alone, the lab initiated 245 new partnerships including 31 more CRADAs.

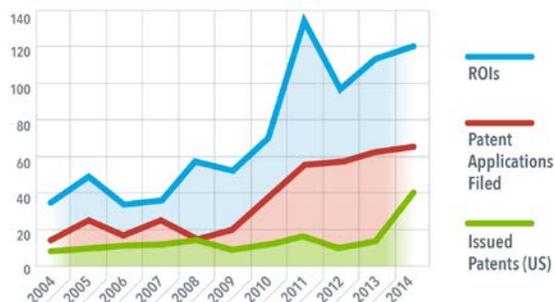
STREAMLINING THE PATH TO MARKET

For a laboratory that works on up to 700 active agreements each year, it's essential to continuously enhance the processes by which those partnerships are established and the mechanisms used to enable commercial partners to move NREL-developed innovations to the marketplace. Recent TTO efforts to make the partnership agreement process easier include:

- ▶ Piloting DOE's newest agreement type—the Agreement to Commercialize Technology (ACT), which was created to address industry requests for greater flexibility in partnership agreement terms than is possible under a CRADA or Work-for-Others agreement.
- ▶ Streamlining NREL's licensing agreement process and refining its licensing agreement template to make it easier for commercial partners to access DOE-funded innovations developed at NREL.
- ▶ Identifying and implementing licensing agreement improvements that better align NREL with industry best practices, and contributing to an effort to standardize those best practices across all of DOE's national laboratories through publication of DOE's Licensing Guide, which aims to provide prospective licensees with an understanding of the typical terms and conditions across most DOE laboratory intellectual property license agreements.

In addition to improvements to its partnership agreements, TTO developed the "Invention Evaluator" to assess new NREL innovations across eight parameters and provide a dynamic "score" that factors in elements of each innovation's patentability, commercial impact, and licensing potential.

"The problem we see in the marketplace in general is that if you don't know how to pick the winners, you file for patent protection on everything, and we don't want to do that," said TTO Senior Licensing Executive Eric Payne. This standardized evaluation allows NREL to "prioritize the innovations coming out of \$350 million of annual research to pick the ones with the highest impact on DOE's Office of Energy Efficiency and Renewable Energy's mission space, as well as the clean energy landscape," he said.



Since the Alliance for Sustainable Energy assumed the contract to operate NREL in 2008, all measures of innovation output have tripled, including records of invention, patent applications filed, and U.S. patents issued.

Lastly, NREL developed the Innovation Portal, a centralized repository for all of DOE's innovations that enables users to locate technologies developed with DOE funding and available for licensing. This searchable database of more than 18,000 DOE patent records offers streamlined searching and browsing of patents, patent applications, and marketing summaries. NREL continues to develop capabilities that link complementary innovations across the national laboratory system, including a groundbreaking tool designed to identify bundles of related intellectual property system-wide.

Through such improvements, NREL is continually learning, refining, and becoming more nimble in how it does business. The result is more industry partnerships and greater success in moving NREL-developed innovations out of the lab and into the marketplace where opportunities to impact the economy, energy security, and the environment abound.

"By partnering with NREL," said Farris, "commercial entities—along with other manufacturers, industry partners, and clean energy sector representatives—are able to reduce the risk of bringing innovative technologies to market faster and with more success."

—Written by Karen Petersen

INDUSTRY GROWTH FORUM CULTIVATES CLEAN ENERGY ENTREPRENEURSHIP

NREL'S INDUSTRY GROWTH FORUM BRINGS TOGETHER CLEAN ENERGY ENTREPRENEURS AND INVESTORS TO FACILITATE THE MOVEMENT OF INNOVATION INTO THE MARKETPLACE.



Panel discussion at the 2013 Industry Growth Forum. From left: Michael Knotek, Deputy Undersecretary for Science and Energy, DOE; Tom Morehouse, Principal Deputy Asst. Secretary of Defense, Operational Energy Plans and Programs, DOD; Dan Arvizu, NREL Director; Ilan Gur, Program Director and Technology to Market Senior Advisor, ARPA-E; and Rick Brenner, Director, Agricultural Technology Innovation Partnership (ATIP) Foundation.

Most entrepreneurs with promising new clean-energy innovations are thinking big, but starting small. It's often a long, bumpy road from the initial hopes and dreams for a new technology to bringing that technology to market, and creating a successful business. The road is fraught with peril as clean-energy startups face volatile market conditions, economic setbacks, stiff competition, and energy policy uncertainty. That said, the greatest challenges involve bridging the gaps between innovation and investment, the so-called "valleys of death," as fledgling businesses seek the funding necessary to navigate toward successful commercialization.

For nearly two decades, NREL has provided crucial support to the clean-energy marketplace through its annual Industry Growth Forum. The forum brings together business startups, investors, policymakers, and thought-leaders for a two-day gathering each autumn. The event features presentations from the most innovative and promising emergent clean energy companies, chosen through a rigorous and competitive selection process. These presentations are supplemented by provocative education panels featuring industry leaders and experts, along with invaluable organized networking opportunities. The Forum has proved to be the perfect venue for growing cleantech companies to introduce their businesses to a wide range of investors.

INDUSTRY GROWTH FORUM

DENVER ★ COLORADO



Photo by Dennis Schroeder, NREL

"The union of R&D (research and development) successes with a receptive investment community will accelerate renewable energy and energy efficiency technology innovations into the marketplace," said Bill Farris, NREL associate laboratory director. "The relationships built and information shared at the Forum are vital to the advancement of these technologies. NREL is pleased to be able to leverage the convening power of the laboratory to facilitate this critical discourse."

THE FORUM GETS RESULTS

Since 2003, more than 300 companies have presented their businesses at the forum to panels of investors and financial executives. These companies represent a wide range of clean energy technology innovation in solar and wind technologies, advanced engines and renewable fuels, building efficiency, energy storage, and others.

An analysis of data for all of the presenting companies since 2003 shows that the Forum has had significant impact on access to capital for the participating entrepreneurs. These companies have collectively received more than \$5 billion in funding since their initial presentations at the Forum.

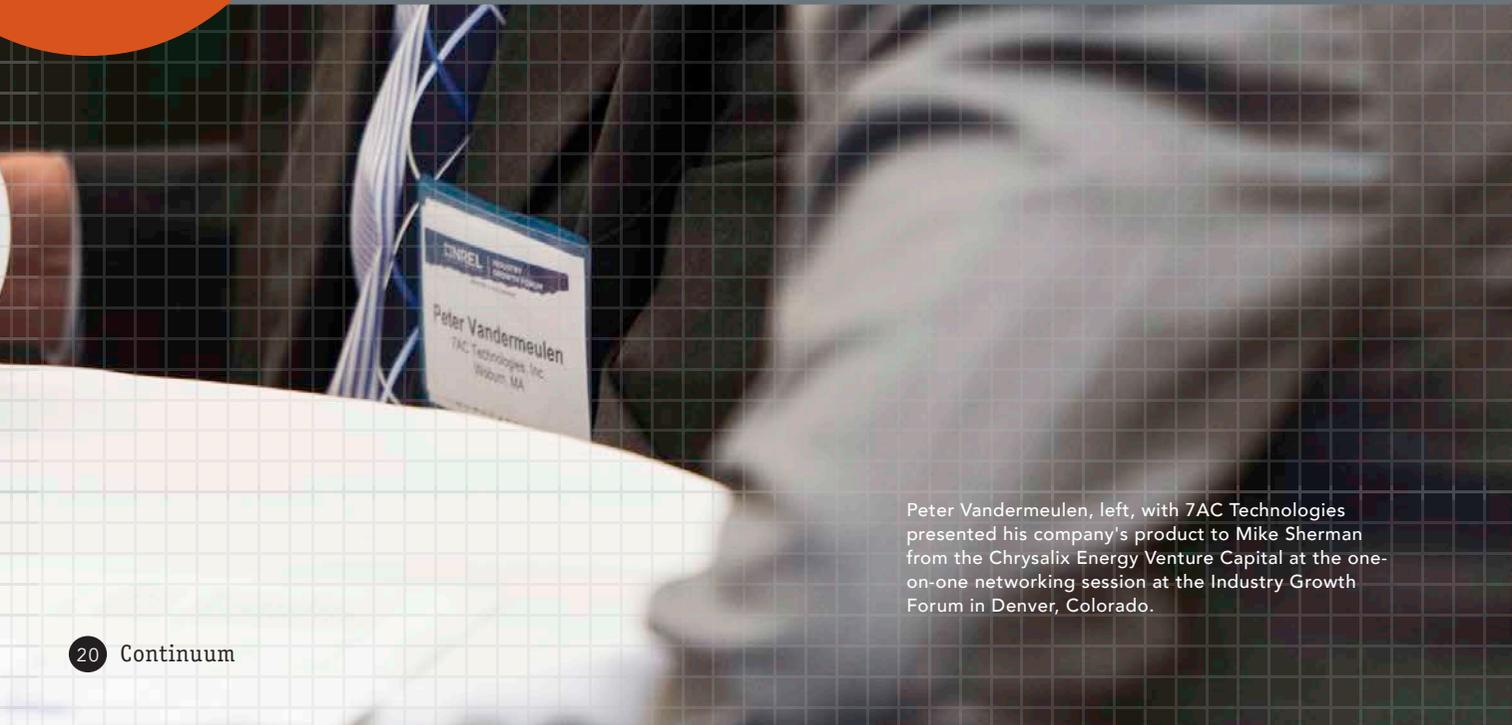
"WE'VE GOT ONE OF THE LONGEST RUNNING EVENTS IN THE CLEANTECH SECTOR AND HAVE BUILT A SOLID REPUTATION FOR PUTTING TOGETHER A VERY HIGH-QUALITY ROSTER OF STARTUP COMPANIES, WHICH MAKES IT AN EVENT NOT TO BE MISSED BY THE TOP INVESTORS."

"The Forum has a proven track record of success for both our entrepreneurial and investor communities," said NREL Project Manager Kate Cheesbrough. "We've got one of the longest running events in the cleantech sector and have built a solid reputation for putting together a very high-quality roster of startup companies, which makes it an event not to be missed by the top investors. Then the presence of those investors sustains the interest from entrepreneurs in being a part of the event the next year, which allows us to maintain and grow the quality of the program."





"AN ANALYSIS OF DATA FOR ALL OF THE PRESENTING COMPANIES SINCE 2003 SHOWS THAT THE FORUM HAS HAD SIGNIFICANT IMPACT ON ACCESS TO CAPITAL FOR THE PARTICIPATING ENTREPRENEURS. THESE COMPANIES HAVE COLLECTIVELY RECEIVED MORE THAN \$5 BILLION IN FUNDING SINCE THEIR INITIAL PRESENTATIONS AT THE FORUM."



Peter Vandermeulen, left, with 7AC Technologies presented his company's product to Mike Sherman from the Chrysalix Energy Venture Capital at the one-on-one networking session at the Industry Growth Forum in Denver, Colorado.

RENEWABLE ALTERNATIVES FROM GOOD CHEMISTRY

Few companies that have presented at the Forum better demonstrate the effectiveness of the event more than OPXBIO, a renewable biochemical and biofuel company based in Boulder, Colorado. OPXBIO uses its proprietary leading EDGE™ (Efficiency Directed Genome Engineering) technology to manufacture renewable bio-based chemicals and fuels that are lower cost, higher return, and more sustainable than existing petro-based products.

A 2010 presenting company, and winner of an Outstanding Venture Award at the event that year, OPXBIO has raised more than \$50 million in equity investment and project funding since its participation in the Forum. Additionally, the company has entered into joint development agreements with significant industry partners and has positioned itself for the commercial launch of their first bio-based chemical products in 2016.

"Participating in the NREL Forum was a valuable experience for OPXBIO," said Charles Eggert, OPXBIO president and chief executive officer. "The NREL Forum supported the success of our equity financing round in 2011 and subsequent establishment of our strategic partnerships. We enhanced our visibility and credibility with potential investors and partners, broadened our network of contacts and relationships, and fine-tuned our company pitch based on feedback from the review panels."

A REVOLUTIONARY HEATING AND COOLING SOLUTION MAKES WAVES

A recent Forum success story comes from 7AC Technologies. 7AC, a startup based in Beverly, Massachusetts, has developed a membrane-isolated plastic plate technology that enables the design of highly efficient liquid desiccant-based heating and cooling solutions. Systems using this technology can drastically cut heating and cooling energy costs while radically improving dehumidification performance.

Since presenting their business at the 2012 Forum and winning the Outstanding Venture Award for that year, 7AC has made significant progress in moving its technology toward commercialization. The company has since put demonstration projects in place, signed a number of agreements with large heating and cooling system manufacturers to further test the technology, and demonstrated that the technology can be scaled to high-volume manufacturing.

"The NREL Forum helped us gain critical visibility among investors and strategic partners, and also gave us great exposure within the HVAC (heating, ventilation, and air conditioning) community," said Peter Vandermeulen, 7AC chief technology officer. "We've made some great

connections that can lead to partnership or investment opportunities. We continue to participate because of these connections and the opportunity to update them on our progress."

A BREEDING GROUND FOR CONTINUED PARTNERSHIP

Companies like OPXBIO and 7AC Technologies that present at the Forum might operate in very different technology areas, but one thing they have in common is a continued collaboration with NREL researchers.

OPXBIO partnered with NREL on a U.S. Department of Energy ARPA-E (Advanced Research Projects Agency-Energy)-funded bioenergy project. The collaborative effort, completed in 2013, sought to develop a bioprocess for the conversion of carbon dioxide and hydrogen gas feedstock to fatty acids and renewable fuels. Their partnership with NREL provided OPXBIO with critical access to NREL technology and research talent to support the success of the project.

7AC Technologies also has a cooperative research and development agreement to demonstrate and test its technology in NREL's Thermal Test Facility, where it has shown an energy efficiency ratio that is 50% to 80% higher than conventional dedicated outside air HVAC systems. The company also engaged with NREL to develop a simulation model that has proved useful in predicting how its technology will behave in various conditions and situations, as well as helping improve and optimize the system.

"The connection to the laboratory is what makes the Industry Growth Forum one-of-a-kind and an extremely effective program," Cheesbrough said. "There are many other business forums that network startup companies with potential investors. But, in addition to just doing that, we are also able to interface these companies with the capabilities of our world-class research staff. The nexus of the networking opportunities at the Forum with the R&D expertise in the labs is where NREL can really make an impact in moving these technologies to market."

—Written by David Glickson

HELPING FORT CARSON MEET DOD ENERGY GOALS

Photo by Dennis Schroeder, NREL



This 4.7 megawatt solar photovoltaic array at Ft. Carson Army Base in Colorado Springs is just one piece of a complex strategy to cut energy intensity at the base and reach the Army's Net Zero Energy Initiative goals.

NREL'S DIVERSE PROJECTS WITH THE DEPARTMENT OF DEFENSE AT FORT CARSON GUIDE ENERGY IMPROVEMENTS THAT ARE MOVING THE ARMY TOWARD ITS VISIONARY ENERGY GOALS.

As the nation's largest single user of energy—spending an estimated \$19 billion on fuel and electricity in 2013—the Department of Defense (DOD) is highly focused on advancing energy security, mitigating costs, and enhancing military capability through energy improvements.

Due to its leadership in researching, developing, and coordinating energy solutions to power our nation's homes, businesses, and transportation, NREL is strategically positioned to help DOD accelerate the implementation of its clean energy initiatives. For several years and through multiple agreements, NREL has brought this expertise to its partnership with a Colorado neighbor to the south, Fort Carson, Colorado.



The U.S. Army garrison mountain post, established in 1942 outside Colorado Springs, is the second largest employer in the state of Colorado and has a \$1.3 billion per year impact on the local economy. Fort Carson hosts 10,000 soldiers—7,000 single soldiers in barracks and about 3,000 married soldiers in on-base family housing.

The two-mile wide by five-mile long post includes an airfield with six operating gates. In the past five years, Fort Carson's building square footage has increased by about 50%, mainly due to the growth of its soldier population. This growth, in combination with the aggressive energy goals of DOD and the U.S. Army, keeps energy efficiency and renewable energy at the forefront of work there.

NREL has supported Fort Carson on several efficiency projects, formed lasting partnerships, and completed instrumental planning, all of which contributed greatly to Fort Carson's visionary net zero-energy objectives. NREL is helping Fort Carson meet its net zero-energy, water, and waste by 2020 goal by conducting technology demonstrations and providing support for micro grid and buildings projects among other efforts.

"We've been working with Fort Carson for over five years, supporting a wide variety of energy efficiency and renewable energy projects including a 2-megawatt photovoltaic (PV) power purchase agreement, net zero-energy planning and implementation, electric vehicle integration, microgrid design, technology demonstration projects, and low-energy building design," said NREL Project Lead Kate Anderson.

"Our success at Fort Carson stems from the knowledgeable and motivated energy managers who believe in the mission and always find a way to make economically viable projects happen," said Anderson.

ARMY NET ZERO ENERGY INITIATIVE

NREL works with nine Army pilot projects to establish energy baselines, estimate energy efficiency and alternative energy potential, evaluate grid interconnection, and develop an implementation plan as part of the Army Net Zero Energy Initiative (NZEI).

A net zero-energy installation produces as much energy onsite as it uses over the course of a year. At Fort Carson, NREL is working with the Assistant Secretary of the Army, Installations, Energy, and Environment to achieve net-zero energy by 2020. Fort Carson volunteered to be an integrated net-zero installation, which means they will be net zero-energy, water, and waste.

The base's goal is to cut energy intensity 30% from 2003 levels by 2015, striving for a 50% reduction by 2020, in addition to its NZEI goals. Several avenues have been used to fund energy efficiency projects including Sustainment, Restoration, and Modernization (SRM); Energy Conservation Investment Program (ECIP); and Environmental Security Technology Certification Program (ESTCP) demonstrations. Several completed and planned construction projects have included

renewable energy technologies such as PV, solar hot water, ground source heat pumps, and transpired solar walls.

"NREL's partnership with Fort Carson advances Army energy goals while providing a platform for evaluating generation, energy efficiency, storage, and energy systems integration at a meaningful scale that can be leveraged to achieve national impact," explained Steve Gorin, NREL's director of DOD Energy Programs.

One key component of NREL's work was supporting the completion of a Net Zero-Environmental Assessment for Net Zero implementation. The assessment evaluated more than a dozen sites on Fort Carson, totaling nearly 1,000 acres and documenting the concerns and challenges with developing renewable energy for these sites. This assessment will be a valuable tool moving forward with the evaluation of renewable energy opportunities.

NET ZERO-ENERGY BARRACKS

In one unique project, Fort Carson is transforming 1950s-era barracks into modern Leadership in Energy and Environmental Design-certified office buildings. In partnership with the General Services Administration and Pacific Northwest National Laboratory, the NREL team researched methods for reducing energy use in new and existing buildings, focusing on optimum building envelopes, daylighting, behavior change impacts, and advanced retrofit strategies for maximum energy reduction. Renovations to date resulted in reduced energy use in the building envelope; lighting; plug loads; and heating, ventilation, and air conditioning (HVAC) systems; as well as added renewable energy generation.

In another effort, NREL worked with DOD and U.S. Army Corp of Engineers to develop specifications for a system that integrates PV, plug-in electric vehicles, and a renewable energy management unit with a microgrid system at Fort Carson. During this multi-year project, NREL developed critical modeling tools to optimize the components needed to link vehicles to the microgrid. A microgrid that integrates renewable generation and vehicle energy storage with load management components offers energy security, cost savings, and reliability benefits. Through the coordination of generators and loads, the Fort Carson microgrid makes it possible to maintain electricity delivery to a portion of the facility that is critical to sustained operations.

"Fort Carson has been a very valuable partner for NREL as a test bed for new technologies and energy systems integration strategies that we have subsequently applied at other DOD, federal, and commercial campuses," said Anderson.

Gorin agreed, "Army's leadership in implementing clean, secure, and cost effective energy solutions advances both of our missions, and we look forward to continued collaboration that builds upon our past successes."

—Written by Tina Eichner

IMPACTING INNOVATION & COMMERCIALIZATION: NREL'S PARTNERING FACILITIES

THE AWARD-WINNING ENERGY SYSTEMS INTEGRATION FACILITY IS THE LATEST ADDITION TO NREL'S PARTNERING SITES.



The Energy Systems Integration Facility is among the cutting-edge sites NREL uses to collaborate with its partners.

Photo by Dennis Schroeder, NREL

NREL's partner facilities are hard to resist—and increasingly, savvy collaborators from a range of industries are heading to the lab to collaborate. The latest draw is the new Energy Systems Integration Facility (ESIF), which garnered the 2014 Laboratory of the Year Award from the editors of *R&D Magazine*. The ESIF is helping transform how the United States generates, delivers, and uses energy by modernizing the interplay between energy sources, infrastructure, and data.

The ESIF is not a private resource for NREL researchers, but instead is designed for collaboration. All of the internal labs in the 182,500-square-foot building are connected by the Research Electrical Distribution Bus (REDB), which functions as a power integration circuit capable of connecting multiple sources of energy and interconnecting laboratories and experiments. This functionality allows NREL and its partners to test and simulate what happens when multiple components are connected to the grid. By allowing researchers to engage in examinations ranging from home systems and solar inverters to fuel usage and data, the REDB makes the ESIF a one-of-a-kind world-class testing site.

NREL AND HP COMBINE TO BREAK BOUNDARIES IN ESIF COMPUTING

Creating the concept for the ESIF forged a partnership, and the same R&D 100 editors recently gave a 2014 R&D 100 Award to Hewlett-Packard (HP) and NREL for their collaboration in developing the HP Apollo 8000 System based on the ESIF's Peregrine supercomputer. The system uses component-level warm-water cooling to dissipate heat generated by a supercomputer, thereby eliminating the need for expensive and inefficient chillers in the data center.

At the ESIF dedication in 2013, Paul Santeler, vice president of the Hyperscale Business Group at HP, said the collaboration with NREL on the lab's high-performance computer and data center was the best partnership he's been a part of because both the company and laboratory learned so much—knowledge that will help other data centers.

He noted that when Steve Hammond, director of NREL's Computational Science Center, brought him the concept, he wasn't certain about it. "We were doing something very unique and different—breaking boundaries," Santeler said, adding the partnership succeeded so well that "we're making it commercially available so others can take advantage."

NREL is the partner we needed and wanted for the first-born in the Apollo family," said Nic Dubé, Peregrine's system architect and HP's technical lead for Apollo. "From the NREL perspective, we greatly benefit from these partnerships as well," said Hammond. "We have the opportunity to provide early design input and feedback to our partners to improve the product, and we have the satisfaction of knowing that we contributed to a product we will use and that will help the entire industry."

Together, NREL and HP solved unforeseen hurdles; for instance, while it took almost three weeks to custom build the plumbing for four computer racks in the engineering prototype phase, the partners streamlined the process using modular plumbing so that for phase II, the team installed 18 racks in less than a week—a key improvement for market viability. "They truly enabled the technology to come out," Dubé said. And there are expectations on both sides that the lab and HP will continue to work closely together.

Utilities, too, are exploring the ESIF's potential. Xcel Energy CEO and Chairman Ben Fowke said the ESIF will become even more important now that solar and wind are in many cases cost competitive with fossil fuels. Already, wind forecasting software developed at NREL and elsewhere saved Xcel \$20 million annually.

But the ESIF is not the only site on NREL's campus earning praise—or attracting collaborators. In 2008, *R&D Magazine* gave a special award for the Science & Technology Facility, noting the 71,000-square-foot laboratory was the first federal building to achieve the highest Leadership in Energy and Environmental Design Green Building rating from the U.S. Green Buildings Council.

COLLABORATIONS IN SOLAR ENERGY HELP PRODUCE A WORLD LEADER

One person who has seen plenty of collaborative usage is Tim Gessert, an NREL principal scientist who, along with many other NREL researchers, helped pioneer cadmium telluride (CdTe) solar panels with industry. DOE recognized the lab's role, and NREL's Thin Film Photovoltaic Partnership Project led research and development on emerging thin-film solar technologies in the United States from 1994 to 2009. "In the early years, our primary goal was to understand all the roadblocks the industry was encountering," said Gessert, whose work is often cited in solar energy literature. "We visited the sites to learn about the challenges and there were many first meetings."

In 1991, NREL and an early CdTe manufacturer, Golden Photon, earned an R&D 100 Award for the development of a CdTe photovoltaic (PV) module manufacturing process. By 1996, Golden Photon was able to provide the U.S. Navy with a 25-kilowatt array of CdTe modules. Another early partner, Solar Cells, Inc., proved a thin-film cost structure that gave rise to many start-up thin-film PV companies—and led to

the creation of First Solar, LLC, a leading worldwide PV manufacturer that has benefited from CdTe technology.

First Solar installed CdTe modules at NREL's Outdoor Test Facility in 2003 for long-term, outdoor performance monitoring. The company also enlisted NREL's expertise to help improve light transmission into the electrical junction and understand junction formation and related avenues for performance improvement. This work assisted First Solar's efforts to produce lower cost and higher efficiency thin-film modules.

Together, NREL and First Solar developed a unique process for manufacturing high-efficiency thin-film CdTe cells on low-cost commercial glass. The process, which quickly deposits uniform layers of semiconductor material for solar panels, won a 2003 R&D100 Award and was considered a significant milestone in the race to produce cost-competitive solar energy. "We are still foundational partners in the endeavors to reduce costs," Gessert said, citing a number of ongoing agreements between the lab and First Solar.

And NREL has a strong record with the auto industry. Not only is the ESIF available, but another key facility is the Vehicle Testing and Integration Facility (VTIF), which opened several years ago and is one of the very few places to examine components of electric vehicles, grid integration, and infrastructure.

NREL's Vehicle Thermal Management team is using the VTIF thermal test pad for both light- and heavy-duty vehicle climate control efficiency research with industry partners. For example, a collaboration with Ford seeks to reduce the impact of heating and cooling on electric drive vehicle range by 10% when the climate control is on.

VTIF is also engaged for partnerships with both Volvo Trucks and Daimler's SuperTruck project researching methods to help reduce the 667 million gallons of fuel used for long-haul truck rest period idling in the United States. The goal of this project is to reduce climate control for long-haul truck rest period idling by 30%.

And with the National Wind Technology Center, NREL also has a strong history of partnering with wind energy technology companies, testing turbines and their components. "We're extremely proud and excited to work with NREL and the Department of Energy," said Andy Geissbuehler, vice president and general manager of Alstom Power Wind Business North America. "We chose the right partner. We would like to continue the partnership and work with NREL on off-shore wind."

—Written by Ernie Tucker



R&D 100 AWARDS DEMONSTRATE CLEAN ENERGY LEGACY

NREL HAS WON 57 R&D 100 AWARDS SINCE 1982, MANY OF WHICH LED DIRECTLY TO INDUSTRY SUCCESSES TODAY.

R&D 100 Awards are often considered the "Oscars of Innovation." Awarded annually by *R&D Magazine*, the awards recognize the 100 most technologically significant new products of the year. Competition for the awards is global and fierce, but despite the challenges, NREL has won 57 awards since 1982. From 1989 to the present, there was only one year in which NREL did not win at least one R&D 100 Award.

NREL views the awards as yet another opportunity to get the word out about their technologies, possibly gaining new partnerships along the way. And the lab's track record for making an impact with its awards is impressive.

Many of the awards in NREL's history led directly to industry successes today. Here are a few key examples:

1. In 1991, NREL won an award for its family of airfoils designed for wind turbine blades. These airfoils quickly became the industry standard (see article on page 9, *From the Start: NREL Nurtures a Growing Wind Industry* to learn more).
2. That same year, NREL won an award for the first practical tandem solar cell, in which two thin, lightweight layers of semiconductors worked together to capture more of the sun's energy. The invention launched a thriving industry for space-based solar cells and yielded significant benefits for the space industry, where reducing bulk and weight is a key concern. It also formed the foundation for today's Earth-based concentrator photovoltaic systems, which focus sunlight onto a small solar cell. NREL has since won four R&D 100 Awards for these multi-layer or "multijunction" solar cells, two in partnership with Boeing Spectrolab of Sylmar, California, and one with Emcore Corp. of Albuquerque, New Mexico, both of which are major suppliers for the space solar power industry.





Energy Secretary Ernest Moniz (center) joins NREL Director Dan Arvizu (left) and Steve Hammond, director of NREL's Computational Science Center, in unveiling Peregrine—the U.S. Department of Energy's newest supercomputer capable of 1 million billion calculations per second—on Sept. 11, 2013. NREL collaborated with HP and Intel to develop an innovative warm-water, liquid-cooled supercomputer that later won an R&D 100 Award.

3. A 1993 winner, "Ethanol from Corn Fiber," spells out how enzymes can be used to help free carbohydrates from corn fibers, allowing them to be fermented into ethanol. NREL followed that up in 1995, earning an award for developing *Zymomonas mobilis*, a bacterium that can convert biomass-derived sugars into ethanol with few byproducts. In 2004, NREL's work to improve the enzymatic process with enzyme companies Novozymes Biotech, Inc. and Genencor International (now part of DuPont) won another R&D 100 Award. Today, a nascent cellulosic ethanol industry is being built, with several companies using the enzymatic approach.
4. In 1994, the lab won for its work with Conserval Engineering, Inc. to develop the transpired solar collector, a device mounted on the south wall of commercial

on cells fabricated by Crystal Solar and collaborated with the company's technical team to develop and implement modifications to the measured cells, contributing to improved cell performance and reliability.

NREL also won an award in collaboration with HP for the HP Apollo 8000 System, a supercomputer that is cooled with warm water. The efficient design eliminates the need for expensive and energy-wasting chillers in the data center, while also allowing the waste energy from the computer to heat its host building, the Energy Systems Integration Facility, during the winter.

As a prime example of energy integration itself, the supercomputer provides an important pathway forward for high-performance computing, which is facing physical limitations. Although the industry is aiming to boost

"NREL CONTINUED ITS WINNING STREAK IN 2014, EARNING TWO R&D 100 AWARDS, BOTH OF WHICH WERE SUBMITTED WITH INDUSTRY PARTNERS."

buildings to pre-heat ventilation air before it is drawn into a building. Conserval continues to sell the product under the brand name "SolarWall," and NREL uses the collectors on two of its buildings, including its highly efficient office building, the Research Support Facility.

5. In 2000, NREL, Northern Power Systems (NPS), NASA's Ames Research Center, and the National Science Foundation won an award for the North Wind 100/20 Wind Turbine, a 100-kilowatt wind turbine that is ideal for extreme cold conditions. The direct-drive, low-maintenance turbine has been extensively deployed in Alaska, and NPS continues to sell the product.

These are just a few examples of the impacts of NREL's R&D 100 Award-winning technologies. The award winners run the gamut of energy technologies, including analytical devices; insulation; air conditioners; batteries; biomass gasifiers; wind turbines; solar cells; and etching, deposition, thermal treatment, defect mapping, quality control, and coating technologies for solar cells.

NREL continued its winning streak in 2014, earning two R&D 100 Awards, both of which were submitted with industry partners. Crystal Solar worked with NREL to demonstrate a new process to manufacture thin-film silicon solar cells. The process uses epitaxy, which involves growing crystals of silicon on a crystalline substrate that has a similar structure.

Although epitaxy is usually a slow process, the new process is 100 times the speed of conventional epitaxy reactors and produces solar cells at half the cost. NREL performed characterization and reliability measurements

performance by another factor of 1,000, achieving those levels with today's technologies would require an entire power plant to service one supercomputer. The HP solution reduces the power needs of the supercomputer while also meeting other energy needs, lowering the total energy impact of installing a supercomputer.

—Written by Kevin Eber



CLEAN ENERGY INNOVATION AT NREL

Continuum

Continuum is NREL's publication that showcases the laboratory's latest and most impactful clean energy innovations and the researchers and unique facilities that make it all happen.

CONTINUUM MAGAZINE EDITORIAL TEAM

Kim Adams, Managing Editor

Bill Gillies, Creative Director

Kakie Atwell, Project Manager

Jennifer Josey, Editor

The images featured in Continuum Magazine can be found at www.nrel.gov/continuum/images.



As the only U.S. national laboratory singularly focused on advancing renewable energy and energy efficiency, NREL's mission spans the spectrum of clean energy solutions—including pioneering research in solar, wind, biomass, hydrogen, and geothermal energy. With 37 years of successful innovation from fundamental research and analysis through commercializing and deploying energy efficiency and renewable energy solutions, NREL continues to pave the way toward clean energy transformation.



National Renewable Energy Laboratory

15013 Denver West Parkway, Golden, CO 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/MK-6A42-62831 • October 2014

NREL prints on paper that contains recycled content.

Photo by Dennis Schroeder, NREL



A CLOSER LOOK

Take a CLOSER LOOK into how NREL supports Colorado's cleantech industry by visiting www.nrel.gov/closer_look