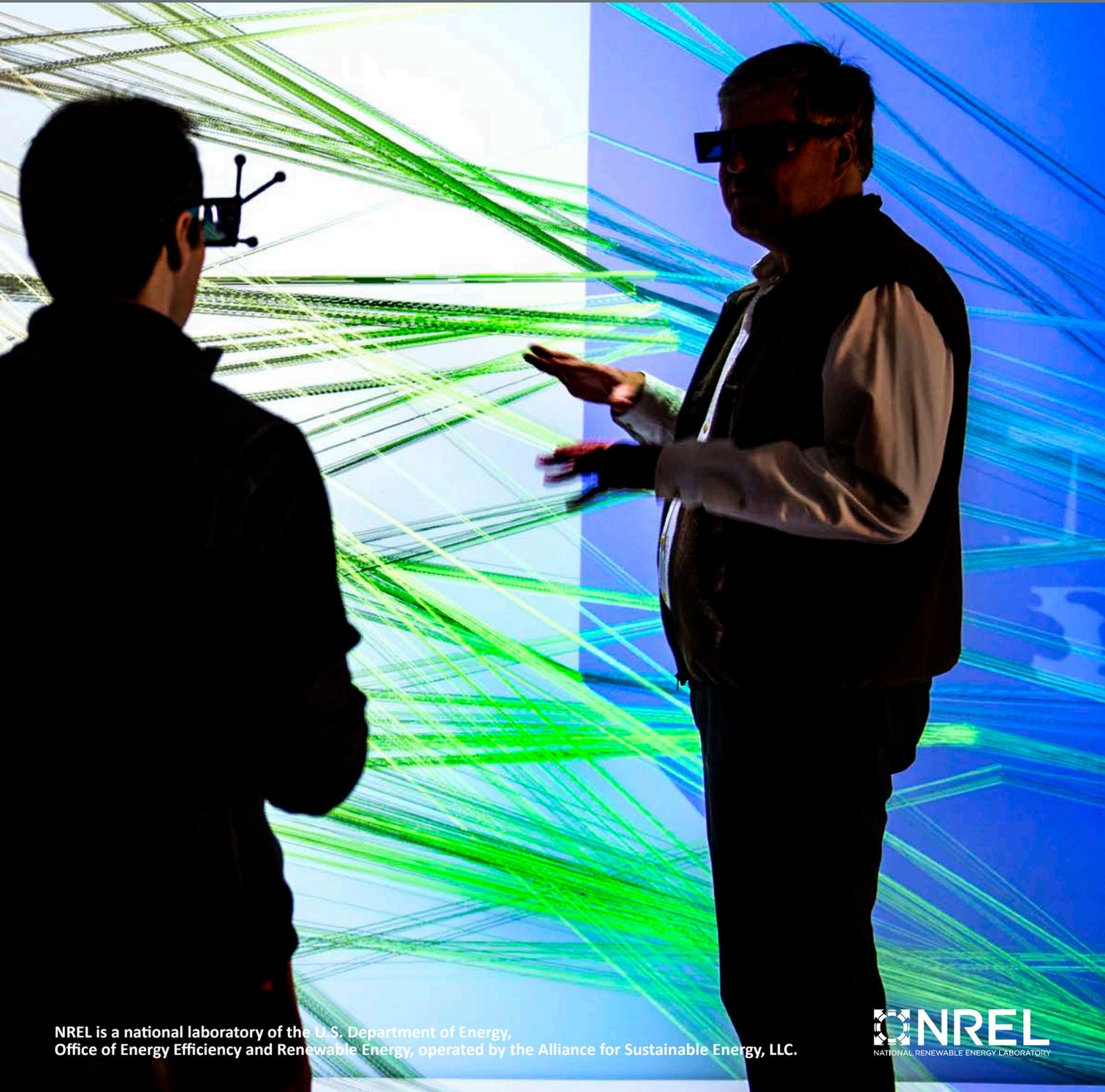


CLEAN ENERGY INNOVATION AT NREL

Continuum

NREL ANALYSIS: REIMAGINING WHAT'S POSSIBLE FOR CLEAN ENERGY



DAN SAYS

NREL ANALYSIS: REIMAGINING WHAT'S POSSIBLE FOR CLEAN ENERGY

An objective, credible analysis capability has been part and parcel of the mission of the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) since our inception as the Solar Energy Research Institute in 1977. Our founders understood the vital role of providing technology-neutral analysis to ensure that innovations developed in the lab fit the needs of the energy consumer. Today, NREL continues to develop tools that increase our understanding of energy policies, markets, resources, technologies, and infrastructure, as well as the connections between these tools and economic, environmental, and security priorities.

This issue of *Continuum Magazine* covers the depth and breadth of NREL's ever-expanding analytical capabilities. For example, in one project we are leading national efforts to create a computer model of one of the most complex systems ever built. This system, the eastern part of the North American power grid, will likely host an increasing percentage of renewable energy in years to come. Understanding how this system will work is important to its success—and NREL analysis is playing a major role. We are also identifying the connections among energy, the environment and the economy through analysis that will point us toward a “water smart” future.

We know that our future will likely include many energy technologies—not just renewables. And NREL's growing body of work on the nexus of natural gas and renewable energy offers insights on transforming our energy economy to include multiple energy options.

On the business and financial front, NREL analysis leadership is helping to identify and overcome barriers with accessing capital that prevents pension and mutual funds from investing in solar power. And in the domestic manufacturing arena, NREL sees opportunities for the United States to use and manufacture clean energy technologies, which can improve the environment and our economy. You can also read about how NREL analysis is making a difference on our roads. Fleet managers and individual drivers alike can use the innovative data found in NREL's suite of transportation tools to green up their travel decisions.

NREL's analytical work doesn't stop at our nation's borders. We collaborate with partners around the world to build global networks that support low-emission economic development. Within these networks, developing countries can partner with subject matter experts to gain insights into, and assistance with, the incorporation of renewable energy into national power systems.

I invite you to read more about how NREL decision science and analysis capabilities guide energy systems transformation at home and around the world. Join me in reimagining what's possible for clean energy.

Dr. Dan E. Arvizu, Laboratory Director



Contents

SUMMER 2015

02

MAKING A COMPUTER MODEL OF THE MOST COMPLEX SYSTEM EVER BUILT

The eastern part of the North American power grid will likely host an increasing percentage of renewable energy in years to come, and NREL wants to see how that will work.

08

CONNECTING THE MOVING DOTS

Systems-level thinking illuminates the connections among energy, the environment, and the economy as NREL analysts help find a path to a “water smart” future.

> 15

NREL HELPS COUNTRIES BUILD STRONGER ECONOMIES WITH LOW-EMISSION DEVELOPMENT

NREL is helping advance the economies of developing countries in a healthy and sustainable manner by providing assistance through partnerships with various countries and institutions across the globe.

> 20

NREL'S WINNING HAND OF CLEAN TRANSPORTATION TOOLS

Fleet managers and individual drivers alike can use the innovative data found in NREL's suite of transportation tools to green up their travel decisions.

> 24

ASSESSING R&D OPPORTUNITIES FOR CLEAN ENERGY TECHNOLOGIES

NREL sees opportunity for the United States to use and manufacture clean energy technologies, which can improve the environment and our economy.

> 18

NREL-LED EFFORTS HELP BRING FINANCING TO SOLAR PROJECTS

NREL is helping remove barriers that prevent pension and mutual funds from investing in solar power.

> 30

OUR TRANSFORMING ENERGY ECONOMY: PATHWAYS TO A DECARBONIZED FUTURE

A growing body of work on the nexus of natural gas and renewable energy offers insight on a transforming energy economy.

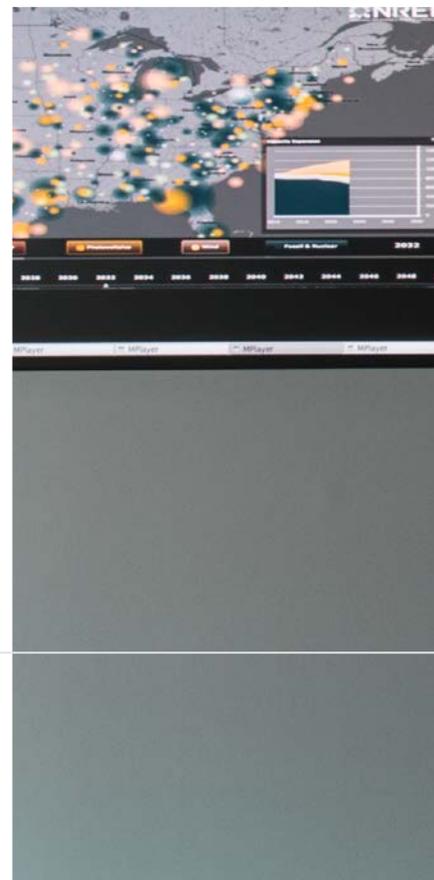


Photo by Dennis Schroeder, NREL

MAKING A COMPUTER MODEL OF THE MOST COMPLEX SYSTEM EVER BUILT

The eastern part of the North American power grid will likely host an increasing percentage of renewable energy in years to come, and NREL wants to see how that will work.

In the coming decade, the eastern part of the North American power grid, called the Eastern Interconnection, will likely host an increasing percentage of renewable power. Understanding how it could handle that transition is the focus of an intensive, multi-year modeling project at NREL.

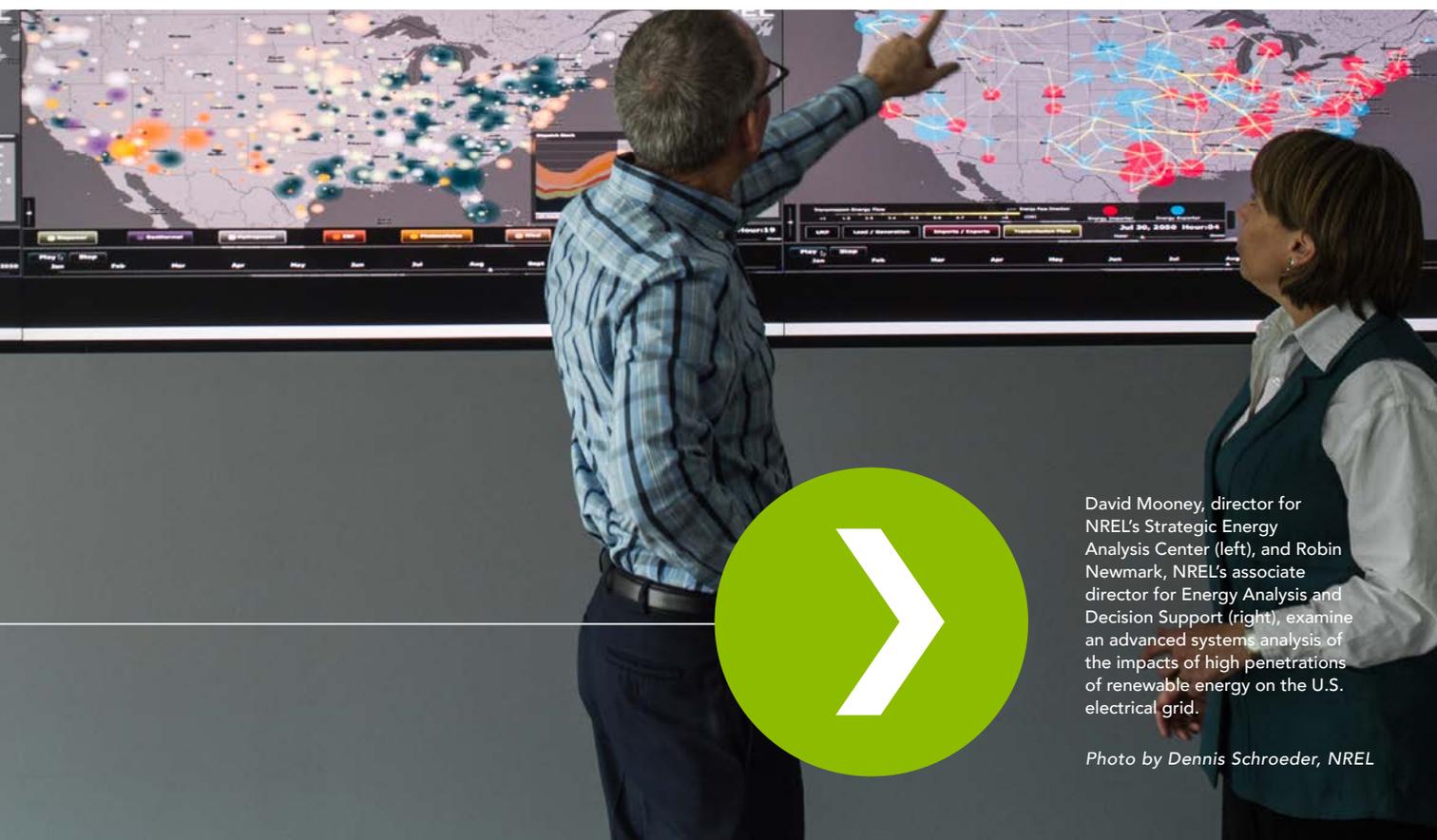


The project, called the Eastern Renewable Generation Integration Study (ERGIS), looks ahead to the year 2026 and examines how the Eastern Interconnection might function under four future scenarios. The Eastern Interconnection runs from the east coasts of the United States and Canada all the way to the western borders of the Dakotas, Nebraska, Kansas, and Oklahoma, while skirting around most of Texas. It serves 70% of the U.S. load and 240 million people, and consists of 50,000 transmission lines spanning 459,000 miles. In short, it's huge, and accurately modeling the entire system at five-minute intervals for an entire year has never even been attempted—until now.

"ERGIS is the highest-resolution simulation of the largest power system in the world," said Aaron Bloom, senior project manager at NREL. "It really is the most complex integration study that we've ever done."

ERGIS is also the first high-resolution model of the *entire* Eastern Interconnection, including Canada.

"Modeling Canada was critically important to this study because of the massive amounts of electricity trade that happen between those two regions," said Bloom. "Indeed, the amount of trade that we can expect to see in the future will be substantial."



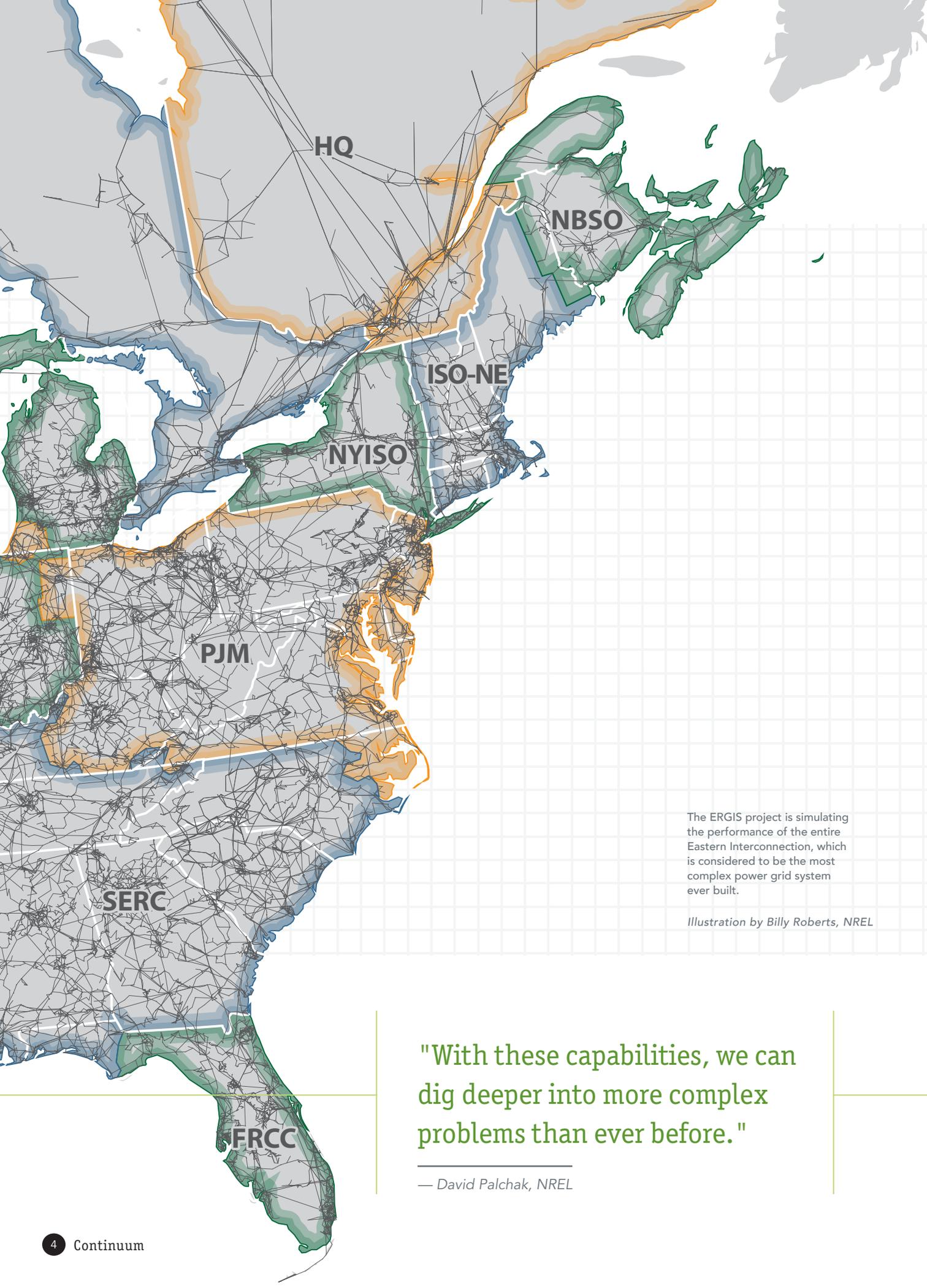
David Mooney, director for NREL's Strategic Energy Analysis Center (left), and Robin Newmark, NREL's associate director for Energy Analysis and Decision Support (right), examine an advanced systems analysis of the impacts of high penetrations of renewable energy on the U.S. electrical grid.

Photo by Dennis Schroeder, NREL

"It really is the most complex integration study that we've ever done."

— Aaron Bloom, NREL

To accurately model system operations for the Eastern Interconnection, NREL worked with a Technical Review Committee (TRC) composed of more than 30 industry experts. Under the guidance of the TRC, NREL developed a complex representation of the power plants, or generators, that power the system; the energy-consuming towns and cities, or "loads"; and the complex network of transmission lines that connect the generators to the loads. NREL's resulting ERGIS database closely mirrors existing Eastern Interconnection system operations.



The ERGIS project is simulating the performance of the entire Eastern Interconnection, which is considered to be the most complex power grid system ever built.

Illustration by Billy Roberts, NREL

"With these capabilities, we can dig deeper into more complex problems than ever before."

— David Palchak, NREL



OF SUPERCOMPUTERS AND MODELING TRICKS

Modeling a huge system like the Eastern Interconnection gets unwieldy quickly. First, a lot of data needs to be fed into the model for it to reach meaningful conclusions; much of these data did not exist before the ERGIS project was launched. For instance, the ERGIS Solar Dataset used 2006 satellite data to estimate actual solar power production at five-minute intervals, and employed a weather model to derive solar power forecasts for four hours ahead and one day ahead—the same type of forecast a grid operator would use to plan ahead. Similar datasets have also been generated for wind power, hydropower generation, and loads in the Eastern Interconnection, all as a function of time. All told, that’s about 1,000 gigabytes of data.

Fortunately, NREL has the world’s most energy-efficient supercomputer to shoulder the computational burdens. Called Peregrine, the system is capable of 1.3 trillion calculations per second—in computer lingo, 1.3 petaFLOPS. NREL also developed new capabilities to deploy the leading industry tool for modeling power grids—PLEXOS® Integrated Energy Model software—on Peregrine’s parallel computing environment.

PLEXOS is able to model how grid operators would make their decisions throughout each day. This includes making “unit commitments”—essentially, plans to turn generators on or off—every hour, one day in advance, while also “dispatching” power plants—telling them how much power to produce—at five-minute intervals. As the modeling software steps forward in time, those decisions affect how the grid operates under changing weather conditions.

“The mathematical challenges associated with a model this complex required the team to build new computational tools to both simulate and analyze the system,” said David Palchak, NREL energy systems engineer. “With these capabilities, we can dig deeper into more complex problems than ever before.”



FINDING A FASTER SOLUTION

For ERGIS, NREL modeled all 7,500 generators in the Eastern Interconnection and all the places where transmission lines interconnect, called buses. In the Eastern Interconnection, there are more than 60,000 buses, making the simulation quite complex. In fact, as NREL initially approached the problem, a simulation of the entire Eastern Interconnection at five-minute intervals for one year would have required more than 400 days of computing time. Clearly, a faster solution was needed.

A key issue was that each day’s solution depended on the solution for the previous day, so there was no obvious way to solve for multiple time intervals in parallel. But NREL researchers realized they could break the simulation into weekly time periods, with two to three days of overlap between each time period, to dramatically reduce the solve time while still capturing most if not all of the generator starts and stops and other metrics needed to form a coherent view of the grid’s performance. This approach allowed NREL to simulate an entire year’s operation in only 17 days of computing time—more than an order of magnitude faster than the conventional approach.

Peregrine is capable of running up to 1,442 programs in parallel—in computer terminology, it has 1,442 “nodes.” These nodes allowed NREL to break up the huge simulations required for ERGIS into smaller chunks that could all be processed at the same time.

“Peregrine’s capabilities allow us to run one week of ERGIS simulations on individual nodes of Peregrine; we can run 52 nodes at a time and therefore run the entire year in parallel,” said Aaron Townsend, NREL’s technical lead on the project. “We did, at times, simulate multiple scenarios at the same time, so we used up to 500 nodes simultaneously, or approximately 35% of the machine.”

To test the model, NREL researchers ran the simulation for 2010 and compared it to the actual performance of the grid during that period. Although the outcomes of the simulation and the actual performance didn’t completely line up, the differences were easily explained, and overall, the TRC found the model to be an accurate depiction of Eastern Interconnection operations.



NREL's Peregrine supercomputer, capable of performing 1 million billion calculations per second, drew on 1,000 gigabytes of data to model one year's behavior of the entire Eastern Interconnection (see illustration on page 4) in only 17 days. Despite the immensity of the task, each scenario used only about 3.6% of the supercomputer's capacity.

Photo by Dennis Schroeder, NREL

WHAT ERGIS WILL TELL US

For ERGIS, NREL is examining four scenarios for 2026:

- ▶ A low-variable-generation scenario, which holds the current amount of wind and solar power constant, removes generators slated for retirement, and adds new generators to meet the load and maintain reliability, as needed.
- ▶ A "regional transmission 10% variable generation" scenario, which builds out wind and solar generation to meet 10% of the interconnection's load with a regional transmission expansion.
- ▶ A "regional transmission 30% variable generation" scenario, which requires wind and solar generation within each of the ERGIS regions to provide 30% of the region's power. This scenario shares the same transmission expansion as the second scenario.

- ▶ An "inter-regional 30% variable generation" scenario, which chooses the best resources in the Eastern Interconnection to meet the 30% target and includes a substantial build-out of new inter-regional transmission facilities.

"What we're looking at is the operational impact of high penetrations of wind and solar on system operations," said Bloom. "How does it change the operations of other generators, like the thermal plants? Do they ramp more, do they start up and shut down more, are they sitting online at idle more often, or are they running full bore all the time? So we want to see what happens to the other power plant assets when you add all these renewables, and then determine if it can be done."

To answer these questions, Bloom and his colleagues are now completing their analyses, and results are expected this summer.



STANDING ON THE SHOULDERS OF GIANTS

ERGIS will be NREL's most sophisticated modeling of a power grid, but it is far from the first. ERGIS is a follow-on study to the Eastern Wind Integration and Transmission Study, the Western Wind and Solar Integration Study Phase 1 and Phase 2, and other analyses. These studies show that the variability and uncertainty of wind and solar power at high-penetration levels require new ways of planning and operating electric power systems. However, new questions are being posed about the impacts of future policies, distributed generation, and the siting and timing of new non-renewable generation and transmission. ERGIS will address these follow-up questions and place additional emphasis on the question of how to plan and operate the Eastern Interconnection in the face of generation and transmission uncertainty.

"These studies continue to show the same thing, which is that the integration of large amounts of renewables into our power grid is technically feasible, and we can integrate a lot of variable generation and continue to operate the system in a way that maintains reliability and meets the demands of the system,"

pathways to make it happen and the challenges associated with each of those pathways, so we can begin to address them. Some changes will have to be made, and these studies are showing that if we make the right changes, we can integrate large amounts reliably and reasonably cost-effectively."

As everyone awaits the ERGIS results, high penetrations of renewable energy are already a fact in Hawaii. The Hawaii Solar Integration Study is a detailed technical examination of high penetrations of wind and solar energy on the operations of the electric grids of Maui and Oahu. The study found that adding large amounts of new solar power to the electric grids on these islands—enough to achieve 20% renewable energy—will create operational challenges that could affect grid reliability, but also recommended a variety of mitigation strategies that could address those challenges while optimizing the use of renewable energy. The ERGIS report is likely to include similar findings.

Meanwhile, NREL's Renewable Electricity Futures Study found that renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total

"What we're looking at is the operational impact of high penetrations of wind and solar on system operations."

— Aaron Bloom, NREL

said David Mooney, director for NREL's Strategic Energy Analysis Center. "That's a really important, fundamental consistency throughout these studies.

"Not only do the reports show that the grids can handle high penetrations of renewables, but perhaps more important is that they identify the

U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the country. That finding, and the coming ERGIS report, should give the nation hope as it moves toward a carbon-neutral energy future.

—Written by Kevin Eber



NREL's Jordan Macknick tests water by the Excel Zuni Power Plant in Commerce City, Colorado.

Photo by Dennis Schroeder, NREL



CONNECTING THE MOVING DOTS

Systems-level thinking illuminates the connections among energy, the environment, and the economy as NREL analysts help find a path to a “water smart” future.

NREL analysts provide insights into the nexus between energy and water use issues. Their work has supported federal and local agencies, as well as other stakeholders, as the nation transitions into a future where the energy-water nexus will become integral to both the nation’s power system and environment.

This work plays into NREL’s and the U.S. Department of Energy’s (DOE’s) missions in a number of ways, including through a project with the U.S. Department of Interior (DOI) meant to address economic, energy, and water-use issues at the Navajo Generating Station (NGS) in Arizona.

The three massive chimneys rising up from NGS appear almost serene against the backdrop of the desert on the Navajo Indian Reservation near Page, Arizona. But a closer look reveals that there is more than meets the eye in this picture.

“It is a microcosm of everything you could imagine going on in one plant,” said Scott Haase, an NREL senior engineer and the lab’s liaison to the DOI.

Haase, who is among a number of NREL staff providing support for DOI and its Bureau of Reclamation, said the issue is complex. Power

sector, transmission, and environmental concerns are in play; there are people who want renewables to be transitioned into the mix; in the arid Southwest, energy-water nexus challenges are paramount; economic development demands and tribal interests remain present; and a carbon emission ruling challenges the status quo.

The 2,250-megawatt coal-fired power plant was built in the 1970s, partially by the federal government, which retains about a quarter share of ownership in the plant—as do a number of partners, including several utilities. The plant has a major impact on the region. NGS provides electricity to Arizona, California, and Nevada, and is vital to the economies of the Navajo Nation and Hopi Tribe by using tribal coal and providing many well-paying jobs. It also supplies low-cost power for pumping water from the Colorado River into the vital Central Arizona Project, or CAP.

The CAP was designed and built by the Bureau of Reclamation to supply water to customers in Arizona, and is an integral part of legal settlements with Indian tribes over water rights.

However, because the plant is near 11 national parks or wilderness areas—the Grand Canyon is only 15 miles away—there are concerns that it contributes to haze. Parks are designated as high priority visibility under the Clean Air Act, and as a result, the U.S. Environmental Protection Agency (EPA) has taken a series of actions to help improve air quality. Those measures involve new standards for nitrogen oxide (NOx) emissions at the plant, leading to a series of negotiations about the plant's future—a process that has highlighted the complex connections linking energy, the environment, and the economy in the area.

While it might seem helpful to try to “connect the dots” to find a solution, NGS presents a situation where the dots are more like three dimensional objects, evolving and moving.

“It’s very complicated,” said David Hurlbut, a senior analyst with NREL’s Strategic Energy Analysis Center (SEAC). “You have to be mindful of how these connections will change over time as the economy and technologies change.”

“YOU HAVE TO BE MINDFUL OF HOW THESE CONNECTIONS WILL CHANGE OVER TIME AS THE ECONOMY AND TECHNOLOGIES CHANGE.”

— David Hurlbut, NREL

Hurlbut and others have been tapped by the Bureau of Reclamation to find what’s referred to as a “glide path” for the plant to be modified in the short-term or possibly closed by 2044. “We’re looking for a reasonable transition path to switch from coal to clean energy alternatives in a way that minimizes the economic disruption,” he said.

NO EASY, OR SIMPLE, ANSWERS AT NGS

Yet there are no easy answers, as Hurlbut noted, because “you can’t just unplug the coal plant. That’s overly simplistic.”

Following the EPA’s notice of intent to set a new NOx standard for the plant, DOI asked NREL in 2011 for an objective assessment of the coal plant in terms of EPA’s then-proposed new NOx emission standards.

“The Bureau of Reclamation has enlisted NREL to assist the agency in the development of low-emitting energy alternatives as part of a long-term and incremental replacement approach for the federal interest in the NGS,” said Kevin Black, the Bureau’s NGS program manager for energy development.

Bureau of Reclamation Deputy Regional Director David Palumbo said the alternatives will be determined through a “rigorous analysis combining energy, environmental, and economic factors.” He added that the Bureau and NREL are working with stakeholders who must prepare for changes in future NGS operations by understanding the effect on energy generation, environment impacts, and related economies.



“What we’re doing is taking everything we’ve been doing generally throughout the lab in terms of analysis of solar, wind, and renewable technologies, and focusing on a particular question in a particular situation,” Hurlbut said.

After the 2011 request, NREL analysts burned a different kind of fuel—midnight oil—to complete a study in a matter of months to help inform EPA while the agency drafted a new proposed NOx rule. Their work helped attract wide support from



The Navajo Generating Station is the focus of energy/water nexus issues that radiate far beyond its setting in Pace, Arizona, near the Grand Canyon.

Photo provided by SRP

“THE BUREAU OF RECLAMATION HAS ENLISTED NREL TO ASSIST THE AGENCY IN THE DEVELOPMENT OF LOW-EMITTING ENERGY ALTERNATIVES AS PART OF A LONG-TERM AND INCREMENTAL REPLACEMENT APPROACH FOR THE FEDERAL INTEREST IN THE NGS.”

— *Kevin Black, Bureau of Reclamation*

stakeholders—utilities, non-government agencies, Indian tribes, and others—for the final EPA rule. NREL analysts also provided technical support to DOI for subsequent negotiations with key parties involved in the plant.

NREL continued to provide key systems-level thinking, enabling stakeholders to move forward with an arrangement that essentially reduces NGS output by a third, enabling EPA to issue its final rule in 2013 with stakeholder backing.

“Even if the coal plant continues to operate, things are going to change,” Hurlbut said. “We’re looking at

where the sector is heading regardless of what happens to NGS by taking trends we can observe or expect, and then following them to 2020, to 2030—and providing a plausible range of outcomes.”

Also in 2013, the EPA, DOI, and DOE jointly released a statement outlining goals and acknowledging how difficult the intertwined set of issues surrounding NGS will be to solve, committing themselves to developing a road map. NREL analysts are “providing a knowledgebase they can draw upon to make these agency-level decisions,” Hurlbut said.

THE ENERGY-WATER NEXUS AS PART OF SYSTEMATIC CHANGE

As unique as the NGS situation appears—a microcosm of challenges in one case—it illustrates the increasingly commonplace collisions between water use and energy demands nationally—a crunch that NREL analysts are studying. NREL is prepared to provide insights into the nexus between energy and water use issues.

“The energy-water nexus is a foundational element of our work here,” said NREL’s Jordan Macknick, another SEAC analyst who studies

NREL is equipped with systems-level modeling capabilities to analyze the energy-water nexus across a spectrum of conditions. For example, Macknick has finalized a journal article that characterizes how much water is used by different technologies over their entire life cycle. His work has demonstrated that one great character of renewable technologies such as photovoltaic (PV) and wind energy generation is that they require zero water for operation. “These are essentially drought-proof,” he said.

NREL is also examining how water resource constraints may affect the future development

“Something that most people don’t recognize is that the energy sector is the largest user of water in the nation,”

the energy-water nexus. “Something that most people don’t recognize is that the energy sector is the largest user of water in the nation,” withdrawing more of this resource than any other industry. Given the effects of climate change—shifting historical weather and precipitation patterns—water is becoming an energy-security issue, he said. “In order to ensure that we have sustainable sources of energy, we need to use water wisely.”

In the past decade, dozens and dozens of power plants, both in the United States and elsewhere, have had to shut down temporarily or curtail generation because there’s simply not enough water to cool generators. In some cases, plants have had to suspend operations because the water returned to the river system from power plants is too warm, and therefore harmful to the river ecosystems.

and operation of the U.S. energy sector. By implementing water resource constraints into the Regional Energy Deployment System (ReEDS) tool—an electricity system capacity expansion model allowing comparisons of scenarios—Macknick and his collaborators are able to look at how water can affect long-term capacity expansion through 2050. They ask questions such as, if there is a drought or there are legal constraints on freshwater resources, how much water would be available for the energy sector and how would electricity deployment change? The modified ReEDS model also allows analysts to examine if there are opportunities to use alternatives to freshwater, including municipal wastewater or brackish groundwater.



Another study published in a peer-reviewed journal looked at all 1,200 U.S. power plants that use freshwater for cooling. Macknick's team determined that most of those plants could be retrofitted to have zero freshwater usage by using alternative water from wastewater or brackish groundwater sources or by using dry cooling for less than half a penny per kilowatt-hour.

"Water is local," Macknick said. "We have to look at water resource trends happening on a local level." And now, the ReEDS tool has the capacity to analyze the entire nation divided into 134 regions.



Associate Laboratory Director Robin Newmark
Photo by Dennis Schroeder, NREL

The added capability allows NREL to see how the regions affect the overall picture of sustainability, and what steps are needed to ensure a "water smart" electricity future.

That overall picture is one that NREL is monitoring. As Macknick noted, although most of that water is for power plant cooling, water is used throughout the entire lifecycle of all energy technologies for manufacturing, the fuel cycle, and power plant operations. NREL studies are evaluating water usage and providing alternatives to some of those concerns, such as decreasing the amounts of water used in the manufacture of PV cells.

SYSTEMS APPROACH TO GAIN INSIGHTS INTO NEW PATTERNS

As NGS and many other examples show, the issues of connecting energy, the environment, and the economy are complex and becoming more frequent. "The decisions have multiple dimensions," said Associate Laboratory Director Robin Newmark. "If we only fix one part of the problem, we may exacerbate another." She explained that such multifaceted challenges are what drive the analysis team because helping stakeholders around the globe gain a more complete understanding of all the moving parts ultimately leads to better solutions.

Newmark, who leads NREL's Energy Analysis and Decision Support organization, including SEAC and the Joint Institute for Strategic Energy Analysis, was a key contributor to the 2014 National Climate Assessment, which recognized that water quality and quantity are being affected by climate change. This, in turn, overlaps with energy and economy.

"Whether with federal or state agencies, utilities, or other organizations, NREL's systems-level thinking is illuminating the links among energy, the environment, and the economy," Newmark said. "In this way, we're not only connecting the dots for decision-makers, we're connecting the present with a more sustainable future."

—Written by Ernie Tucker

"The decisions have multiple dimensions.
If we only fix one part of the problem,
we may exacerbate another."

— Robin Newmark, NREL

Biorefineries: Clearing The Air



Ryan Davis is a member of the team of NREL analysts modeling biorefinery air emissions and exploring mitigation strategies.

Photo illustration by Dennis Schroeder, NREL

The bioeconomy comes with an implicit promise: It will be clean and sustainable. And while it is believed that the use of fuels made from biomass creates fewer greenhouse gas emissions than traditional fossil fuels, the emission of regulated air pollutants in the production of biofuels is a topic that has been uncertain—until now.

Enter NREL's team of bioenergy analysts. Garvin Heath, Yimin Zhang, Arpit Bhatt, Ryan Davis, and Daniel Inman have undertaken a study, one of the first of its kind, that looks at the potential implications on air quality of a growing biofuels industry. In addition, the team is studying mitigation and permitting strategies.

"Until this study, no one had really taken a look at producing these new fuels and the new biomass conversion process designs in the context of the necessary air permits," said Heath. "This is a new commodity."

Analysis Impacting Design

The biofuels emissions analysis is already having an impact on the biofuels industry. Heath and Zhang are beginning to share the results of their research with permitting and regulatory agencies, as well as providing feedback to the designers of the advanced biomass-to-biofuels conversion platforms. The current analysis followed two promising design platforms: the sugars-to-hydrocarbons process design and the fast pyrolysis process design. Both were developed by NREL, the latter in collaboration with Pacific Northwest National Laboratory, with support from DOE's Bioenergy Technologies Office.

The analysis has resulted in two reports, each specific to a design platform and scheduled for release in summer 2015. "Once we publish our reports and the process designers see the air regulations that need to be met, they can consider how to incorporate design features that mitigate air emissions," said Zhang. "That makes the biorefinery designs more feasible for commercialization because air pollution permits are an absolute requirement for operation."

Air Emissions—Mitigation and Permitting

Biorefineries, like all industrial facilities, are subject to environmental laws, including complex air-quality regulations that aim to protect and improve the quality of the air. These regulations govern the amount of air pollutants (nitrogen oxides, particulate matter, and carbon monoxide, for example) that can be emitted from different types of emission sources.

According to Heath, a preliminary conclusion reached by his team is that biorefineries that use the sugars-to-hydrocarbons process design or the fast pyrolysis process design should be able to be permitted under federal air emissions rules (though state and local rules will also need to be considered).

"Air permits require analysis. There are many decades worth of regulations in the industrial air pollution arena," said Heath. "A new industrial commodity like biofuels will benefit from the advanced research and analysis we're conducting. If there are any concerns, we can flag those ahead of time and improve the systems and thereby help fulfill the sustainability promise."

—Written by Kristi Theis



NREL HELPS COUNTRIES BUILD STRONGER ECONOMIES WITH LOW-EMISSION DEVELOPMENT

NREL IS HELPING ADVANCE THE ECONOMIES OF DEVELOPING COUNTRIES IN A HEALTHY AND SUSTAINABLE MANNER BY PROVIDING ASSISTANCE THROUGH PARTNERSHIPS WITH VARIOUS COUNTRIES AND INSTITUTIONS ACROSS THE GLOBE.





NREL's Caroline Uriarte, Andrea Watson, and Dan Bilello stroll below an array of international flags. The three are a few of the laboratory's key players in global partnerships that assist developing countries with low-emission economic development. Through the partnerships, NREL provides technical assistance to help incorporate renewable energy into national power systems, which strengthens the countries' economies and reduces greenhouse gases.

Photo by Dennis Schroeder, NREL

NREL COLLABORATES WITH PARTNERS AROUND THE WORLD TO BUILD GLOBAL NETWORKS THAT SUPPORT LOW-EMISSION ECONOMIC DEVELOPMENT. THROUGH VARIOUS MEANS WITHIN THESE NETWORKS, DEVELOPING COUNTRIES CAN PARTNER WITH SUBJECT-MATTER EXPERTS TO GAIN INSIGHTS INTO, AND ASSISTANCE WITH, THE INCORPORATION OF RENEWABLE ENERGY INTO NATIONAL POWER SYSTEMS. THUS, THE LAB IS HELPING REDUCE THE GREENHOUSE GASES THAT ARE THE PRINCIPAL CAUSE OF CLIMATE CHANGE—AND IS DOING SO AT THREE LEVELS.

THE POWER OF PARTNERSHIPS

At the highest level, the lab is deeply involved with the 21st Century Power Partnership (Power Partnership). The partnership is an initiative of the Clean Energy Ministerial, a global forum to share best practices and promote policies and programs that encourage and facilitate the transition to a global clean energy economy. NREL and the Joint Institute for Strategic Energy Analysis (JISEA) act as the operating agent for the partnership. Through the Power Partnership, NREL collaborates with both developed and developing countries, and with international clean energy organizations and technical institutes. Dan Bilello, laboratory program manager for the U.S. Department of State and the U.S. Agency for International Development (USAID) programs at NREL, said the partners “develop and share knowledge, strengthen and disseminate tools, bolster expert capacity, and support policy and regulatory analysis.” The Power Partnership’s mission is to advance integrated

policy, regulatory, financial, and technical solutions for the large-scale deployment of renewable energy in combination with deep energy efficiency and smart grid solutions.

Ron Benioff, who leads many of NREL’s multilateral programs, says the Power Partnership recently launched a fellowship program to allow for exchanges of government officials, technical experts, and system operators from countries and institutions across the world to learn from each other. The fellowships will initially focus on India, Mexico, and South Africa.

“We’ve found that most deep learning happens on a peer-to-peer basis,” Benioff said. “Whether it’s a regulator or a grid operator, they’re often most inspired and get the most benefit from interacting with colleagues in other countries who are doing cutting-edge work.”

GLOBAL PARTNERSHIPS ANSWERING ECONOMIC DEVELOPMENT NEEDS

At the second level, NREL works on a country-by-country basis, focusing on specific needs, and employing the concept of Low Emission Development Strategies (LEDS). LEDS promotes sustainable social and economic development while reducing long-term greenhouse gas emissions. The lab works through two LEDS partnerships: 1) Enhancing Capacity for LEDS (EC-LEDS), sponsored by USAID, and 2) the LEDS Global Partnership (LEDS-GP), sponsored by the U.S. Department of State.

EC-LEDS works with more than 20 partner countries to help them transition to low emission and sustainable economic development strategies. Andrea Watson, NREL's project manager for the EC-LEDS program, helps coordinate NREL's role in providing technical assistance and tool development for partner countries.

"We look at both energy efficiency and renewable energy as a way to develop the country's economy while lowering emissions," Watson said.

Jaquelin Cochran, an NREL senior energy analyst, says that within EC-LEDS and the USAID project there is a growing interest among countries in integrating renewables into the grid. EC-LEDS is helping countries map how they're going to meet their renewable energy targets. One example is Mexico: Through EC-LEDS, NREL has written a Grid Integration Road Map to help Mexico implement its ambitious goals for renewable energy.

"We look at both energy efficiency and renewable energy as a way to develop the country's economy while lowering emissions."

— Andrea Watson, NREL

"We are working closely with power system operators, regulators, energy planners, transmission companies, and others to look at what the impact on the grid is," she said. "In some of these countries, the power systems are modernizing and growing very rapidly.

So making changes now can have a really big impact on how the power system develops."

The other partnership, LEDS GP, harnesses the collective knowledge and resources of more than 160 countries and international donor and technical organizations to strengthen climate-resilient, low-emission development efforts around the world. NREL is co-secretariat of the program, and NREL's Caroline Uriarte manages the program with Benioff. The LEDS GP delivers training, expert assistance, and technical collaboration support in three regions: 1) Africa, 2) Asia, and 3) Latin America and the Caribbean.

NONPROFITS REAPING BENEFITS, TOO

Finally, at the third level, NREL has initiated a strategic relationship with the nonprofit community, beginning with the Children's Investment Foundation Fund (CIFF). Via the Power Partnership, CIFF recently committed more than \$3.8 million to pay for technical support—provided by NREL—to enable the government of Mexico to implement the Energy Reform Program in Mexico's power sector. The reform program includes integrating renewable energy and smart grid solutions. CIFF's reasoning for making such a large commitment is that the resulting reduction in greenhouse gas emissions and related criteria pollutants will have a positive effect on Mexico's children.

Sonia Medina, CIFF director for climate change, says, "For children born today, it is likely that the biggest challenge of their adult lives will be climate change. Climate change has the potential to wipe out the gains we make in nutrition, health, education and rising living standards. We are pleased to partner with NREL and help bring its expertise to Mexico and China at a critical moment in the energy reform processes. The depth and breadth of knowledge will help these countries quickly achieve cleaner and lower carbon energy systems. Mexico and China's leadership on energy reform domestically and climate change globally deserve to be widely recognized and supported."

Doug Arent, executive director of JISEA, says CIFF's large investment, "builds off of our thought leadership in power sector transformation. It allows us to expand our technical assistance and our international network of power system experts to strengthen and support Mexico's power sector."

Bilello says CIFF's commitment is indicative of a new trend where nonprofits, which are recognizing the quality of NREL's technical staff and facilities, are now reaching out to partner directly with the laboratory. CIFF has already expanded its relationship with NREL through an additional commitment of nearly \$5 million for technical assistance for renewable energy analysis and planning in China.

—Written by Karen Atkison

NREL-LED EFFORTS HELP BRING FINANCING TO SOLAR PROJECTS

NREL IS HELPING REMOVE BARRIERS THAT PREVENT PENSION AND MUTUAL FUNDS FROM INVESTING IN SOLAR POWER.

From examining the source of costs and estimating specific project costs, to helping large institutional investors direct their funds into solar projects, NREL works on many aspects of solar financing.

Global investment in solar power reached nearly \$150 billion in 2014, a record achievement that included \$14.8 billion invested in the United States. But public financing, such as stocks and bonds, represents a relatively small percentage of that investment: Only \$8.3 billion in public funds were invested in solar power globally, with the United States dominating that total with \$5.9 billion in public market investment. Although the 2014 investment levels were at an all-time high with an increase of 73% globally and 76% in the United States from the year before, they pale relative to the roughly \$73 trillion in public investments held by central banks, pension funds, and sovereign funds around the globe. So how can we get more public investment in solar power?

“There’s a large pool of money that does not invest in renewable energy assets because the investors are not confident on how well the assets perform in the field, and there’s no easy way to trade in and out of security positions,” said NREL Senior Financial Analyst Michael Mendelsohn.

To help connect that pool of money with the solar projects that need low-cost financing, NREL is coordinating the Solar Access to Public Capital (SAPC) working group, which consists of 425 members representing many of the leading solar developers, investment banks, rating agencies, engineering firms, and accounting firms in the United States, as well as some data and analytics firms, all working together to facilitate wide-scale investment in solar assets.

“The basic idea is that, through contract standardization and the use of best practices for

solar power system installation, operations, and maintenance—as well as good-quality data on asset performance—we can allow the cash flows from solar projects to be pooled into tradable liquid securities and give investors the tools to conduct the due diligence and analysis necessary to build confidence in how these investments will perform,” said Mendelsohn.

Just as mortgages and auto loans are pooled into securities that are easily bought and sold, with a price set by the market, solar project loans could also be pooled into such liquid securities.

“There’s really no wide-scale investment mechanism for solar power that’s easily traded,” said Mendelsohn. “This builds the foundation, at least, for these liquid securities to be formed.”

BUILDING A SUPPORT STRUCTURE FOR SOLAR LOANS

While working to build such wide-scale investment mechanisms, NREL is also helping to open lending opportunities for individual solar projects, in part by helping the banking industry understand solar technologies and their performance. NREL began addressing this issue through the Banking on Solar working group, which pulled together 100 leading banks, credit unions, regulators, state green banks, developers, and analytical firms to build consensus on appropriate underwriting principals and develop a support structure for solar loans. Banking on Solar is now a subcommittee of the SAPC working group, which is funded by the U.S. Department of Energy’s Sunshot Initiative under its Advanced Financing to Achieve Sunshot program.

The main stumbling block for solar loans is assessing the risk of the investment, so the SAPC working group also focuses on lowering that risk by developing best practices in system installation



“There’s really no wide-scale investment mechanism for solar power that’s easily traded.”

— Michael Mendelson, NREL



Photo by Dennis Schroeder, NREL

and maintenance, constructing performance datasets to understand and mitigate any production risks, and engaging rating agencies to facilitate secondary market sales or securitization of solar loans.

NREL engineers also get down and dirty with specific solar projects, analyzing proposed projects for their capital costs, operating costs, power production, and overall economic performance, as well as any risks involved, to help investors assess the projects. Again, this is a case of lowering the perceived risk for investors to help the projects gain financing.

NREL’s work on assessing solar projects and lowering the risk of solar loans should make solar projects easier to finance. Furthermore, pulling together a large number of solar loans will provide an easily traded, liquid investment vehicle for pension funds, mutual funds, and other investors. Across the entire spectrum—from individual projects to tradable liquid securities—NREL is working to channel investments into solar projects, helping drive down costs and increase deployment of solar power throughout the United States and the world.

—Written by Kevin Eber

NREL'S WINNING HAND OF CLEAN TRANSPORTATION TOOLS

FLEET MANAGERS AND INDIVIDUAL DRIVERS ALIKE CAN USE THE INNOVATIVE DATA FOUND IN NREL'S SUITE OF TRANSPORTATION TOOLS TO GREEN UP THEIR TRAVEL DECISIONS.

A truly sustainable transportation future will only gain traction and widespread adoption if everyone—from policymakers, to fuel providers and fleet managers, to individual drivers—makes thoughtful, informed choices about the greenest way to get from point A to point B. But you can't make significant decisions without powerful information. That kind of action requires some powerful tools—which NREL has in spades.

ALTERNATIVE FUELS DATA CENTER: THE ROYAL FLUSH OF ADVANCED TRANSPORTATION INFORMATION

The Alternative Fuels Data Center (AFDC), a resource of the U.S. Department of Energy's Clean Cities program administered by NREL, is an online portfolio of information related to alternative fuels and advanced transportation technologies. The website is a powerhouse for all kinds of decision makers—supplying resources for fleets to reduce petroleum use or an individual considering the purchase of an all-electric vehicle, and everyone in between.

As a means of providing this information, the AFDC features more than a dozen tools, including the Vehicle Cost Calculator, Laws and Incentives Data, Petroleum Reduction Planning Tool, BioFuels Atlas, and more.

NREL developed most of the AFDC tools, but as Johanna Levene, a manager in the Strategic Energy Analysis Center for the team that runs the AFDC, pointed out, "We easily pull in and partner with different national labs and organizations. The site is very much a clearinghouse for unbiased alternative fuels data and information."

According to Levene, the most popular AFDC tool is the Alternative Fueling Station Locator. The tool allows users to find stations that offer electric vehicle charging, E85, biodiesel, natural gas, propane, and hydrogen. The data can then be sorted by geographic location, along a route, by public or private stations, or by payment options.

The information can now be accessed in a variety of ways as well, which has broadened





Large-scale fleet companies, such as UPS, use the AFDC Station Locator to plot their routes and determine how to fuel their propane (or other alternative fuel) vehicles as few times as possible and as efficiently as possible.

Photo from UPS

“BUT THE BIGGEST BENEFIT OF THE STATION LOCATOR IS GIVING USERS OR POTENTIAL USERS THE PEACE OF MIND THAT REFUELING THEIR VEHICLE IS NO LONGER A CHALLENGE.”

— Tucker Perkins,
Propane and Education Research

its appeal. “Users of the Station Locator now have the ability to download and slice and dice any of the data into a spreadsheet for easy analysis,” said Levene. “We now have an iPhone app and we’ve developed a widget for organizations and companies, like BMW and Nissan, to embed code in their websites and allow access to the locator information.”

One satisfied end-user of the Station Locator is Tucker Perkins, chief business development officer for the Propane Education and Research Council. A self-described “alternative fuel advocate of 30 years,” Perkins has spent much of his adult life driving propane fuel vehicles and is an avid supporter of NREL’s work and the data provided by the AFDC.

Perkins knows first-hand that his propane clients rely on the Station Locator, especially during large-scale fleet deployments. According to Perkins, the fleet managers use the Station Locator almost exclusively to plot their routes to fuel their vehicles as few times, and as efficiently, as possible.

“But the biggest benefit of the Station Locator is giving users or potential users the peace of mind that refueling their vehicle is no longer a challenge,” said Perkins. “The locator really begins to give the alternative fuel user, who has made the choice for all the right reasons—for savings to the company, for reduction of imported fuels, for cleaner air and cleaner water in the communities they drive—the security and peace of mind that wherever they travel, they can find a place to fill their vehicle.”



ANOTHER ACE (OR TWO OR THREE) IN THE HAND: FLEET TOOLS

Where the AFDC is geared toward helping fleet managers with research and initial deployment, NREL also hosts a suite of fleet tools, such as the Transportation Secure Data Center (TSDC), Fleet DNA, DRIVE, and FASTSim, to help fleet managers dig deeper into operational efficiencies and match technologies to their specific fleet patterns.

“The charts we made ended up being very helpful in California politicians’ decisions to contribute 10% of their cap and trade funds that limit GHG emissions,” Newmark said. “The TSDC provided useful data for decision-makers. And the state passed what will be a \$65 million increase in affordable housing funding, but will increase to \$500 million per year.”

For Newmark, one of the key benefits to the TSDC is that it makes data collected by a single agency



The TSDC, for example, provides free access to detailed transportation data from a variety of travel surveys and studies, including second-by-second GPS readings for millions of miles of travel, along with vehicle characteristics and demographics. It’s a data storage warehouse that offers invaluable information to decision makers, such as city planners, to help them with road planning or infrastructure needs.

Greg Newmark, senior research analyst for the Center for Neighborhood Technology, is one proponent of the TSDC and the value it can offer. One of Newmark’s recent clients, an affordable housing advocacy group in California, wanted help with a study and he recommended using data from the TSDC.

easily available for free to researchers. “Since so many of the underlying studies for urban analysis are expensive to undertake and receive some amount of federal funding, the TSDC is a fantastic way to get more value out of the initial federal investment,” said Newmark.



STAYING IN THE GAME FOR THE LONG HAUL

“One of the coolest aspects of the AFDC is that it has been around since 1991—it’s not a new asset,” said Levene. “We’ve been sharing these data in all kinds of different formats for a very long time. We have that historical capability and we are known as a trusted source.”



NREL’s Drive-Cycle Rapid Investigation, Visualization, and Evaluation (DRIVE) tool can help organizations, like school districts with large fleets of buses, analyze their vehicle drive cycles to reduce fuel consumption, emissions, and costs.

Photo by Dennis Schroeder, NREL

Levene recalls a day when she heard Google was planning its own type of alternative fuel station locator for its users. “They went to the AFDC and after taking a look, they realized that they couldn’t improve upon the design and functionality, and now they just use our widget,” said Levene.

For most, that would have been equivalent to winning a high-stakes poker match—but not for NREL’s hardworking researchers, developers, and analysts. They continue to work tirelessly to improve on the information and functionality. After all, there’s always more data to capture and more ways to analyze and visualize those data, and they aren’t going to fold.

—Written by Kathy Cisar

Transportation Tools Help Individuals And Companies Make The Right Play

Adam Duran, senior research engineer at NREL and a developer for the DRIVE and Fleet DNA tools, said that many fleets use the tools and analysis to make informed transportation choices that support their economic and operational goals. “But sometimes they want to invest in green technologies to know that they are making a change for the better,” said Duran. “Being able to run the analysis helps them back up their decisions.” Here’s a short list of some of NREL’s most important transportation tools:

ALTERNATIVE FUELS DATA CENTER (AFDC)

- ▶ **Alternative Fuel and Advanced Vehicle Search**
WWW.AFDC.ENERGY.GOV/VEHICLES/SEARCH
Search for heavy- and light-duty alternative fuel and advanced vehicles.
- ▶ **Alternative Fueling Station Locator**
WWW.AFDC.ENERGY.GOV/LOCATOR/STATIONS/
Locate alternative fueling stations and get maps and driving directions.
- ▶ **Laws and Incentives Data**
WWW.AFDC.ENERGY.GOV/LAWS
Search for laws and incentives related to alternative fuels and advanced vehicles.
- ▶ **Vehicle Cost Calculator**
WWW.AFDC.ENERGY.GOV/CALC/
Compare cost of ownership and emissions for most vehicle models.

FLEET TOOLS AND DATA RESOURCES

- ▶ **DRIVE: Drive-Cycle Rapid Investigation, Visualization, and Evaluation**
WWW.NREL.GOV/TRANSPORTATION/DRIVE.HTML
Produce testable drive cycles from real-world vehicle data.
- ▶ **FASTSim: Future Automotive Systems Technology Simulator**
WWW.NREL.GOV/TRANSPORTATION/FASTSIM.HTML
Perform fuel economy, performance, battery life, and cost calculations for different vehicles and usage scenarios.
- ▶ **Fleet DNA: Commercial Fleet Vehicle Operating Data**
WWW.NREL.GOV/TRANSPORTATION/FLEETTEST_FLEET_DNA.HTML
Optimize vehicle designs and choose advanced vehicle technologies for fleets.
- ▶ **Transportation Secure Data Center (TSDC)**
WWW.NREL.GOV/TRANSPORTATION/SECURE_TRANSPORTATION_DATA.HTML
Find detailed transportation data from a variety of travel surveys and studies.



As technologies continue to advance in U.S. wind manufacturing, larger blade designs may, in turn, increase manufacturing opportunities. Because transportation is complicated, larger blades are typically manufactured near the area of use.

Photo by Dennis Schroeder, NREL

ASSESSING R&D OPPORTUNITIES FOR CLEAN ENERGY TECHNOLOGIES

NREL SEES OPPORTUNITY FOR THE UNITED STATES TO USE AND MANUFACTURE CLEAN ENERGY TECHNOLOGIES, WHICH CAN IMPROVE THE ENVIRONMENT AND OUR ECONOMY.

Federal and state governments are enacting policies to encourage adoption of renewables to fulfill the dream of a clean energy future. An expanded line of NREL analyses aims to answer questions about manufacturing clean energy technologies, shedding insight not just on integration of renewables, but also on where those technologies are likely to be built.

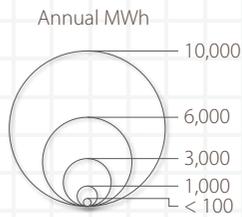
WHAT'S IN A LOCATION?

When considering manufacturing, what drives a factory location decision?

Conventional wisdom says it's often lower labor costs. But that's not necessarily true in the case of solar photovoltaic (PV) panels. A study by NREL and the Massachusetts Institute of Technology found that production scale—not labor costs—create the current advantage for China in the manufacturing of PV energy systems. In addition, Chinese manufacturers have preferred access to capital, and the scale of production helps create a supportive supply chain that helps sustain the industry.

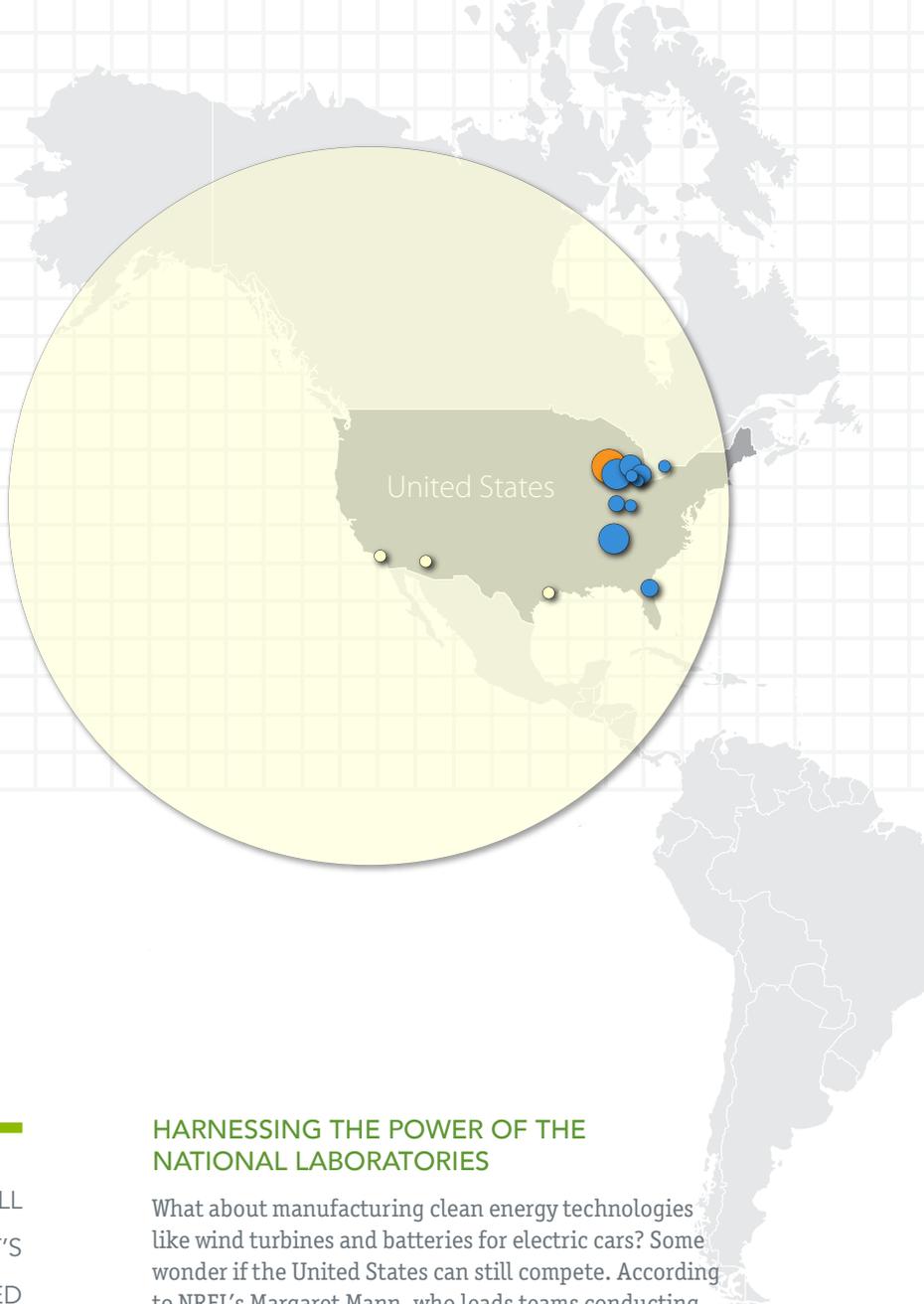
"There is considerable misunderstanding in the global PV industry today about the difference between production cost and sales price, leading to many bad investment decisions," said Paul Basore, who transitioned to a leadership role at NREL following a career in the solar industry. "By defining and focusing attention on the minimum sustainable price of PV-module manufacturing, [NREL and the Massachusetts Institute of Technology] provide a sound basis for decision making by both industry and government."





Status

- Fully Commissioned
- Partially Commissioned
- Under Construction
- Announced



“THERE IS UNDOUBTEDLY STILL OPPORTUNITY HERE, AND IT’S IMPORTANT FOR THE UNITED STATES TO REMAIN COMPETITIVE IN MANUFACTURING.”

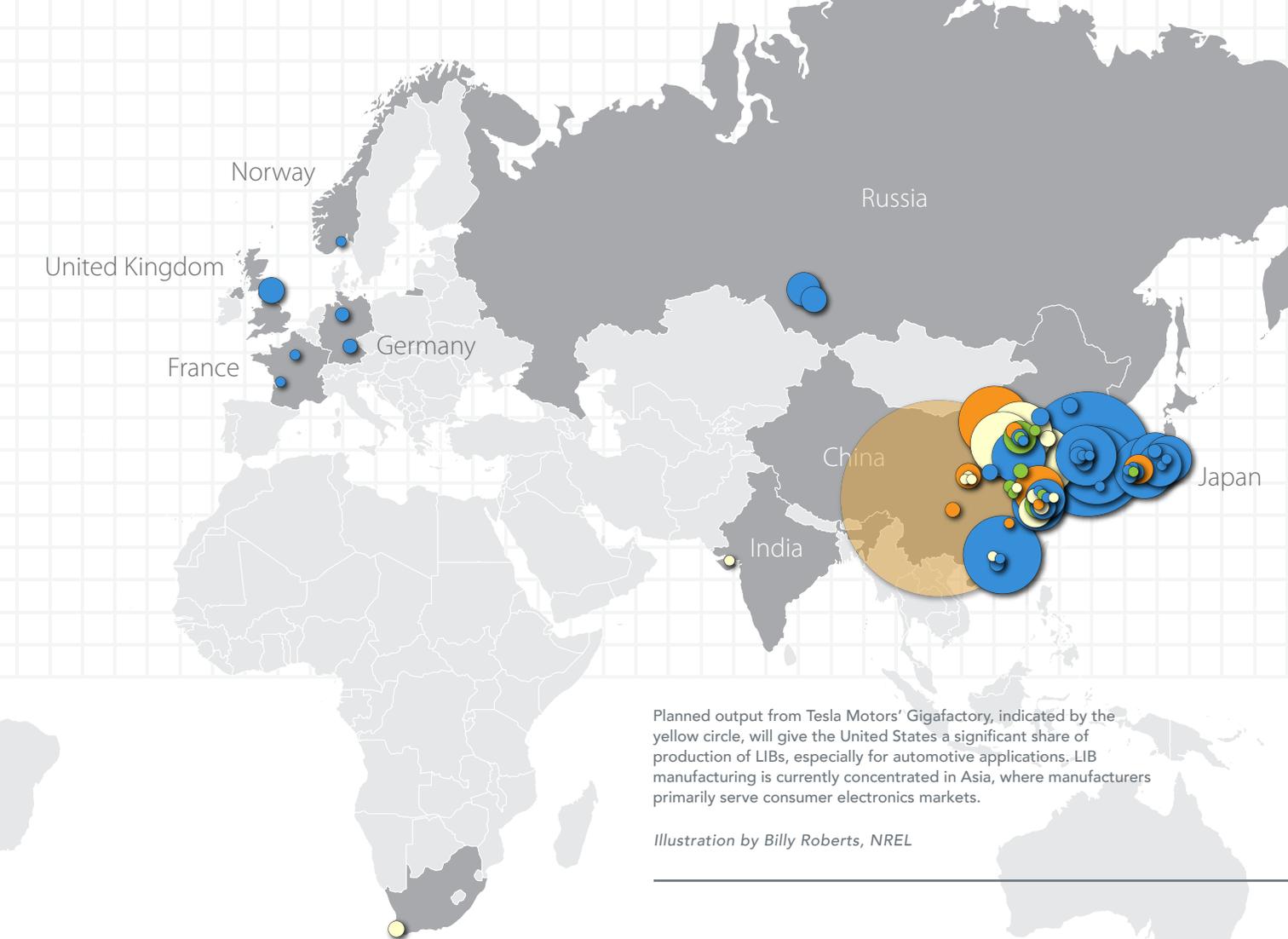
— Margaret Mann, NREL

HARNESSING THE POWER OF THE NATIONAL LABORATORIES

What about manufacturing clean energy technologies like wind turbines and batteries for electric cars? Some wonder if the United States can still compete. According to NREL’s Margaret Mann, who leads teams conducting manufacturing-related analyses, the answer is a resounding yes.

“The United States is still a global leader in manufacturing. In 2011, U.S. output was higher than the combined output of Brazil, Russia, Italy, Germany, and Korea,” said Mann. “There is undoubtedly still opportunity here, and it’s important for the United States to remain competitive in manufacturing.” And, as Mann points out, research and development (R&D) activities tend to cluster around manufacturing centers, so continued capability in manufacturing supports continued capability for innovation.

This is where NREL’s new Clean Energy Manufacturing Analysis Center (CEMAC) comes in. Funded by the U.S. Department of Energy’s (DOE’s) Clean Energy Manufacturing Initiative and operated by the Joint Institute for Strategic Energy Analysis, CEMAC harnesses the world-class talent of the DOE national laboratory



Planned output from Tesla Motors' Gigafactory, indicated by the yellow circle, will give the United States a significant share of production of LIBs, especially for automotive applications. LIB manufacturing is currently concentrated in Asia, where manufacturers primarily serve consumer electronics markets.

Illustration by Billy Roberts, NREL

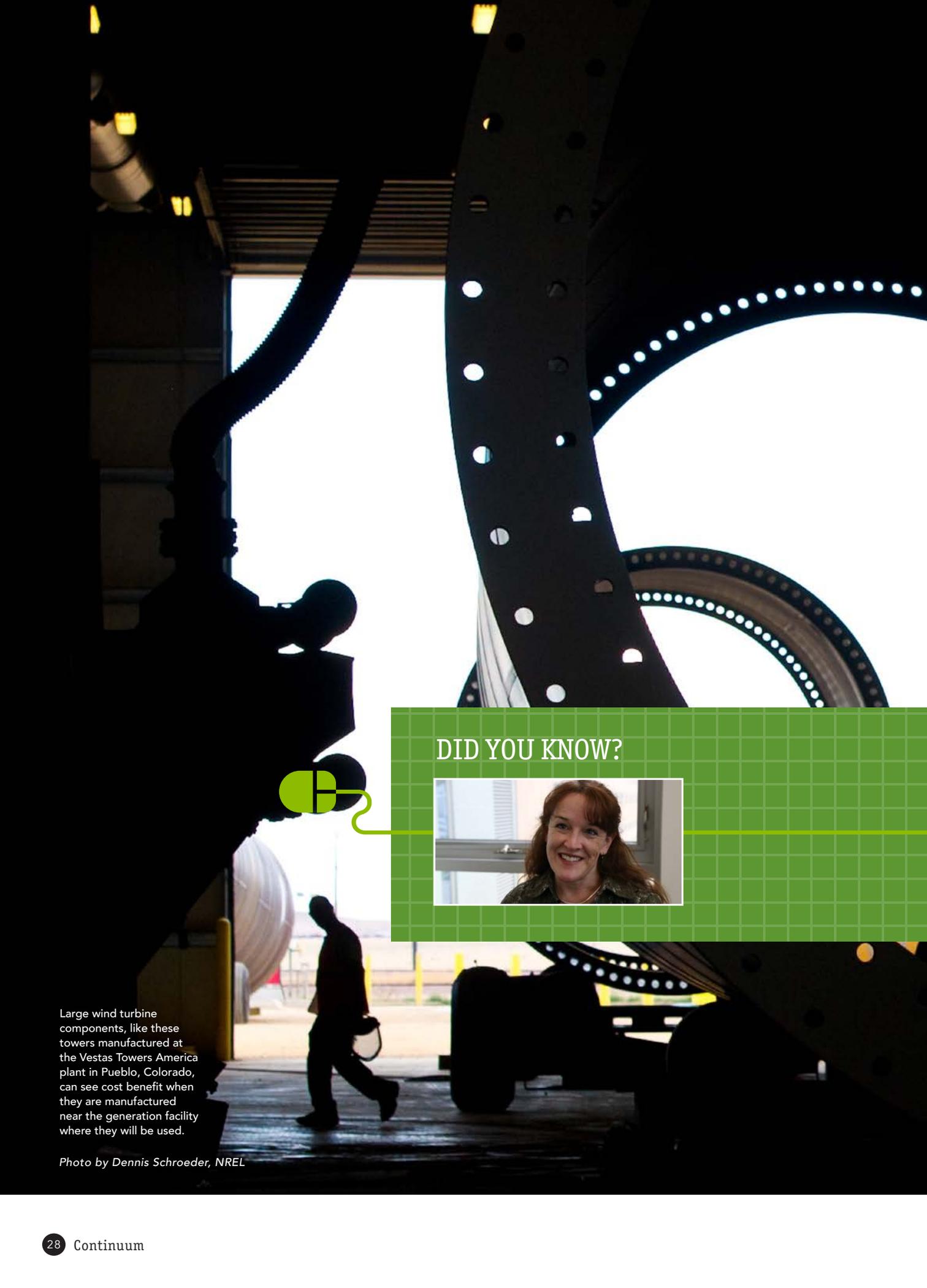
network in partnership with industry, universities, and research affiliates to provide objective insights. These insights can then be leveraged by decision-makers to inform investment strategies, policy, and other decisions, promoting economic growth and competitiveness in the transition to a clean energy economy.

“As we build on the foundational analysis that NREL has conducted on the cost of manufacturing PV technologies, and explore manufacturing opportunities for other clean energy technologies, we’ll be able to better understand the manufacturing, as well as market deployment, economic, and sustainability benefits,” said Mann.

DOE and the national laboratories are uniquely fitted to tackle analysis challenges in clean energy manufacturing. To date, national laboratories have pioneered manufacturing analysis for energy technologies, developed analytical models and methodologies, curated extensive input data, and trained experts in cost structures of clean energy technologies. In the process, the national laboratories have become equipped to house sensitive information and have earned the trust of industry and policymakers alike.

As it takes flight over the coming years, CEMAC seeks to establish itself as a primary source for credible and objective global clean energy manufacturing analysis. Ultimately, CEMAC seeks to provide data and insight that policymakers and industry can use to promote economic growth and the transition to a clean energy economy. Already, NREL is conducting manufacturing-oriented analyses for multiple technologies that span the portfolio of DOE’s Office of Energy Efficiency and Renewable Energy. These include photovoltaics, automotive lithium-ion batteries (LIBs), heat pumps, and energy-efficient lighting.

“We are examining clean energy industry trends; cost, price, and performance trends; market and policy drivers; and the future outlook for these technologies,” said Mann. “My hope is that we can continue to add manufacturing analysis to our way of thinking. This would allow us to provide insights to help DOE program offices and our other clients allocate their R&D funds in such a way as to increase the likelihood that clean energy technologies developed in the United States will be manufactured in the United States.”



DID YOU KNOW?



Large wind turbine components, like these towers manufactured at the Vestas Towers America plant in Pueblo, Colorado, can see cost benefit when they are manufactured near the generation facility where they will be used.

Photo by Dennis Schroeder, NREL

INDUSTRY OPPORTUNITIES ABOUND

So where is the opportunity in these industries? Below are some examples from CEMAC's work:

- ▶ Significant wind manufacturing capacity has been built in response to the growing domestic market, and recent manufacturing production levels exceed anticipated near-term domestic demand for select parts in the supply chain. As technologies advance, larger blade designs may increase U.S.-based manufacturing opportunities. Larger blades tend to be manufactured near the area of use because transportation is costly and difficult.
- ▶ Potential growth of the electric vehicle market could create additional opportunity for U.S.-based manufacturers to also capture a portion of the automotive LIB market in certain economic conditions. NREL research indicates these conditions are feasible. Indeed, Tesla Motors, an American designer and manufacturer of electric vehicles, is already investing in domestic production of LIBs. Tesla's so-called Gigafactory, now under construction in Nevada, is scheduled to begin production in 2017. By 2020, Tesla estimates the factory will produce more LIBs than were produced worldwide in 2013. Tesla will use these batteries in its own electric vehicles and other applications, leapfrogging over the supply chain established elsewhere for consumer electronic devices. If Tesla achieves the anticipated production scale of its Gigafactory, the United States will be a dominant player in LIB production, as portrayed in the illustration on pages 26 and 27.
- ▶ Researchers in manufacturing competitiveness have found that developing a breakthrough technology, such as advanced automotive or stationary batteries, is more likely if innovation takes place alongside manufacturing. Manufacturing activity also supports establishment and growth of robust supply chains, which can be essential to manufacturers who wish to scale up production.

DOE national laboratories are pioneers in manufacturing analysis for energy technologies. They have developed analytical models and methodologies, curated extensive input data, and trained experts in cost structures of clean energy technologies; in turn, earning the trust of industry and policymakers alike.

Meet NREL innovator Maggie Mann and learn how her work in clean energy manufacturing analysis contributes to a cleaner energy future by visiting www.nrel.gov/continuum/analysis/manufacturing.html.

The U.S. economy is creating a growing demand for energy-efficient buildings, as well as cleaner vehicles and sources of energy. Growing demand makes NREL's work in manufacturing analysis all the more vital to national economic, environmental, and security objectives. According to Mann, "With insight provided by our manufacturing analysis, DOE, industry, and others can understand the global markets and trade flows for clean energy technologies, and from there see where opportunity may exist for U.S. leadership in the manufacturing and use of these technologies."

—Written by Kendra Palmer

OUR TRANSFORMING ENERGY ECONOMY:

A GROWING BODY OF WORK ON
THE NEXUS OF NATURAL GAS AND
RENEWABLE ENERGY OFFERS INSIGHT ON
A TRANSFORMING ENERGY ECONOMY

Natural gas and renewable energy—two abundant, domestic forms of energy—are often cast in antagonistic roles. But a growing portfolio of studies by the Joint Institute on Strategic Energy Analysis (JISEA) is showing that natural gas and renewables can each contribute—sometimes independently, sometimes together—to economic growth, energy independence, and carbon mitigation. This is good news for consumers and other stakeholders within the changing U.S. energy landscape.

GETTING THE RIGHT PEOPLE TOGETHER

JISEA, through NREL and its other partners, has the credibility and prestige to gather the most influential stakeholders and thought leaders for lively exchanges on the dynamics, issues, and opportunities facing the natural gas and renewable energy industries.

In 2014, for example, JISEA hosted the NG-RE *360 Degrees of Opportunity Forum*, a series of workshops in different locations with different focuses. New York City brought together the investment community; Washington, D.C., considered national policy; and Texas and California represented states where natural gas and renewables both play a significant role in the economy. A new report, *Pathways to Decarbonization: Natural Gas and Renewable Energy: Lessons Learned from Energy System Stakeholders*, captures key insights and common themes, analytics that complement workshop topics, and pathways for further studies.

Prior gatherings emphasized that natural gas electricity generation enjoys low capital costs and variable fuel costs, whereas renewable energy generators have higher capital costs but generally zero fuel costs, excluding bioenergy. Within the power sector, natural gas and renewable energy industries have typically viewed each other as direct competitors. But an NREL technical report, *Natural Gas and the Transformation of the U.S. Energy Sector: Electricity*, and a JISEA-authored

article in *The Electricity Journal*, *Interactions, Complementarities and Tensions at the Nexus of Natural Gas and Renewable Energy*, have scoped out the complementary aspects of energy sources.

In the transportation realm, natural gas is a key input in producing corn-starch-based ethanol fuel. And new transportation infrastructure and technology could enable the use of natural gas and renewable fuels in vehicles. Both energy sources support a future built environment designed for local energy supply and use, including distributed generation and home vehicle fueling.

MAKING A STRONG BUSINESS CASE

JISEA analysts have delved into the technical intricacies of natural gas and renewables. But they have also explored how the two resources working together may provide a superior value proposition for businesses. In another report, *Exploring the Potential Business Case for Synergies between Natural Gas and Renewable Energy*, JISEA considered some potential revenue opportunities and concluded that multiple levels of synergy exist between natural gas and renewable energy. Hybrid systems optimizing energy assets are one example, such as “smart” buildings that benefit both from solar photovoltaic systems and natural gas combined heat and power systems. Another example of synergy includes investment portfolios that address business and financial risks through asset diversification.





“To advance a cleaner, decarbonized energy system, we have to look at energy and economic systems in new ways. With this study, JISEA provides a valuable and unique perspective on collaboration rather than competition between natural gas and renewables, and practical insights that can help spur the clean energy economy.”

— Bill Ritter,
Center for the New Energy Economy

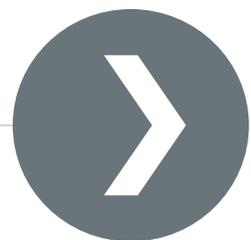
JISEA's focus on the synergy of natural gas and renewable energy provides critical insights within the changing landscape of energy in the United States.

Photo provided by iStock

“To advance a cleaner, decarbonized energy system, we have to look at energy and economic systems in new ways. With this study, JISEA provides a valuable and unique perspective on collaboration rather than competition between natural gas and renewables, and practical insights that can help spur the clean energy economy,” said former Colorado governor Bill Ritter, Jr., director of the Center for the New Energy Economy.

Using illustrations to spur thought, discussion, and action, JISEA analyses examined potential business configurations for synergies in five sectors. The first sector was bulk energy, with synergistic opportunities such as joint transmission corridors, colocation, hybrid energy systems, wholesale power markets, increased coordination, and joint financing.

The other four sectors, at the distribution edge of the electricity and natural gas networks, included industrial, residential, commercial, and transportation end uses. In the transportation sector, for example, synergies could build on shared infrastructure of transitioning to alternative fuel vehicles. The infrastructure could receive multiple forms of fuel, including renewables and conventional gas.



GETTING GAS RIGHT: GUIDING DECISIONS THROUGH ANALYSIS

Decision makers may also want to better understand each technology on its own merits. To this point, several JISEA partners published a *Science* article, *Methane Leaks from North American Natural Gas Systems*, that evaluated the total impact of switching from coal to natural gas to generate electricity. The authors concluded that, to a large extent, switching depends on how much methane, a potent greenhouse gas, leaks from natural gas wells during their lifetime. Although current evidence suggests that leakage may be greater than official estimates, NREL co-author Garvin Heath said, “We identified some cause for concern but found that system-wide leakage is unlikely to be large enough to disfavor coal-to-natural gas substitution.”

“WITHIN THIS STUDY AND OUR LARGER BODY OF WORK FOCUSING ON NATURAL GAS [AND RENEWABLES], JISEA OFFERS POLICYMAKERS AND INVESTORS A SOLID ANALYTICAL FOUNDATION FOR DECISION MAKING.”

— Doug Arent, NREL

Comparing greenhouse gas emissions from various electricity generating options has been another focus of JISEA analysis. A recent *Proceedings of the National Academy of Sciences* article provided estimates of life-cycle greenhouse gas emissions from electricity generated from shale gas. The results are similar to those from conventionally produced natural gas, and both energy sources, on average, emit about half the greenhouse gases of coal-powered electricity.

Doug Arent, executive director of JISEA, concludes, “Within this study and our larger body of work focusing on natural gas [and renewables], JISEA offers policymakers and investors a solid analytical foundation for decision making.”

—Written by Don Gwinner

WHAT MAKES JISEA SPECIAL?

In a word, *insights*.

Since its inception in 2010, the Joint Institute for Strategic Energy Analysis (JISEA) has provided critical clarity and insights to inform decision making through its leading-edge interdisciplinary research and its objective, credible, cross-functional analysis.

Launched by the Alliance for Sustainable Energy, LLC, JISEA draws on the unique capabilities of its founding institutions—NREL, University of Colorado-Boulder, Colorado School of Mines, Colorado State University, Massachusetts Institute of Technology, and Stanford University—and research affiliates around the world to inform the transformation to a clean energy future. For example, JISEA’s impacts can be seen in its growing natural gas research and analysis portfolio; its leadership of the 21st Century Power Partnership to pave the way for decisions related to power systems of the future; and with JISEA and the 21st Century Power Partnership becoming trusted partners with Mexico’s government, which continues to develop its energy reform policies.

“Systems thinking” is an essential discipline for seeing growing connections between energy, the environment, and the economy. And JISEA provides big picture insights—helping policymakers and energy planners understand the impacts of existing and proposed legislation, policy, and investments on renewable energy development and deployment at the local, state, regional, national, and global levels.

The energy picture worldwide is a complex, interconnected system, and JISEA's research and analysis provide valuable insights at both overarching and detailed scales for a variety of energy stakeholders.

Illustration by Peak Creative

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

Dennis Schroeder, Photographer

The images featured in Continuum Magazine can be found at 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.



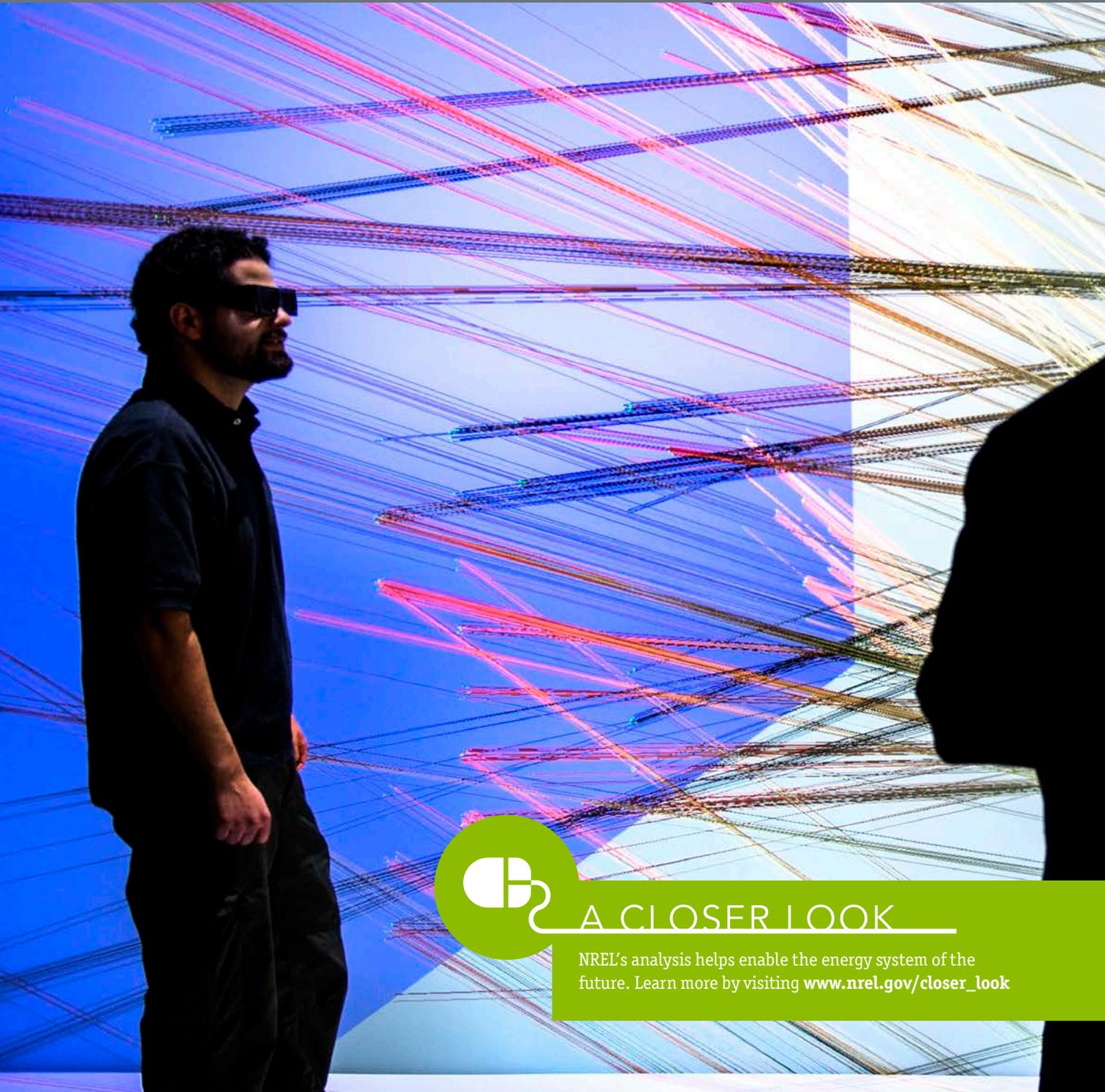
National Renewable Energy Laboratory

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/BK-6A42.64721 • Summer 2015 / Issue 8

NREL prints on paper that contains recycled content.



A CLOSER LOOK

NREL's analysis helps enable the energy system of the future. Learn more by visiting www.nrel.gov/closer_look