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RENEWABLE ENERGY

Wind R&D Newsletter | MAY 2018

IN THIS ISSUE

Letter from the Wind Energy Technologies Office Acting Director

Valerie Reed

In my first letter to you as the Acting Director of the U.S. Department of Energy (DOE) Wind Energy Technologies Office (WETO), I am simply in awe of the continued progress made by the wind industry as I reflect on the past year. Since I joined WETO last fall, I have witnessed a number of milestones for both our office and the wind industry broadly.

In offshore wind, U.S. Secretary of Energy Rick Perry announced in December $18.5 million to establish an offshore wind research consortium. In distributed wind, Primus Wind Power became the first awardee of the Competitiveness Improvement Project to achieve a certified turbine when the Primus Air40 was certified in February 2018.

This past year we also released the 2017 *Peer Review Report*, which summarizes feedback on the office's initiatives and investments across the nation. WETO is using the feedback from peer reviewers to help assess and revise the office's current and future research portfolio, ensuring effective investment of taxpayer dollars. DOE's investments support energy science research and development activities that enable industry innovation to improve the performance and lower the cost of wind energy technologies.

I am proud to say that in the 3 years since the *Wind Vision*'s release, DOE has funded several projects intended to support the goals set forth in the document. With performance improvement in mind, a wake steering experiment at Sandia National Laboratories' Scaled Wind Farm Technology facility showed successfully that the wake of an upwind turbine can be steered away from a downwind turbine. In pursuit of preventing premature turbine failure and lowering maintenance costs, a new wind turbine drivetrain gearbox and main bearing is being validated on-site at the National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory (NREL).

To receive this newsletter by email or to sign up for breaking news on funding opportunities and other topics, go to the Wind Energy Technologies Office's website at ***energy.gov/eere/wind/listings/wind-news***

We're excited to join our friends in the wind industry at the American Wind Energy Association's (AWEA's) WINDPOWER conference. WETO has a lot going on in Chicago—please see page 3 for a schedule of DOE-related events, and visit us at booth #4437 to meet DOE representatives and pick up the latest publications from us and our national laboratories.

Finally, for some additional inspiration while you're in Chicago, be sure to cheer on the future wind industry leaders participating in DOE's Collegiate Wind Competition. The students' bullpens are located near the registration area, and you can view tunnel testing and the KidWind competition in the ballrooms across the concourse.

On behalf of my colleagues and everyone at WETO, thank you for joining me in celebrating the power of wind.

Sincerely,

Valerie Reed
Acting Director, Wind Energy Technologies Office

For more information about WETO's research and development project portfolio, visit our interactive projects map located at *https://www.energy.gov/eere/wind/wind-energy-technologies-office-projects-map*

Groundbreaking Experiment Steers Wake Away from Downwind Turbine

A recently completed wake steering experiment at the Sandia National Laboratories (Sandia) Scaled Wind Farm Technology (SWiFT) facility successfully demonstrated that the wake from an upwind turbine can be steered away from a downwind turbine by yawing the upwind turbine. These results will enable the wind industry to evaluate the potential for yaw-based wake steering to improve the performance of both existing and new wind power plants around the country—which could lead to higher, more predictable output from wind plants and lower operating costs, ultimately reducing the cost of wind energy overall.

The wake of a turbine is a region of lower wind speed and increased turbulence that reduces the power output and increases damaging loads on downwind turbines in its path. By yawing the upwind turbine so that the incoming flow hits the turbine at an angle, the wake deflects laterally. Under the right conditions, the wake can avoid the downwind turbine altogether, leading to higher total energy capture in a wind plant.

Currently, researchers from Sandia and NREL are analyzing the data from the extensive SWiFT site instrumentation. They will calculate the power and loads on the two turbines, along with the wake location as it reacts to the yaw control action. This analysis will quantify the uncertainty in the measurements and the factors that most influence the performance of the wind plant to ensure the results are accurate and reliable.

The technical details of the controller, turbine, and experimental data are all public, helping to facilitate rapid technology transfer from DOE to the wind industry. Information about the experiment and data is available at *https://a2e.energy.gov/projects/wake*

An experiment at Sandia National Laboratories Scaled Wind Farm Technology facility successfully demonstrated wake steering, which will help wind power plants increase energy capture. *Photo by Jon White, Sandia National Laboratories*

WETO AND NATIONAL LAB EVENTS AT AWEA WINDPOWER

MONDAY May 7

12:30 p.m.–4:30 p.m.
Pre-Conference Seminar: Unleashing the Vast Great Lakes Offshore Wind Potential
Walt Musial, *Manager Offshore Wind, NREL*
W183C

TUESDAY May 8

12:00 p.m.–12:25 p.m.
Attitudes of Wind Project Neighbors: Deep Dive with Berkeley Lab Researcher on National Survey
Ben Hoen, *Research Scientist, Lawrence Berkeley National Laboratory (LBNL)*
Thought Leader Theater

1:15 p.m.–4:00 p.m.
Collegiate Wind Competition Student Presentations
Front of Exhibition Hall

1:30 p.m.–1:55 p.m.
Turning a Double Negative into a Positive: What It Will Take To Stay Competitive in the Face of Rising Interest Rates and the Loss of the PTC
Mark Bolinger, *Research Scientist, LBNL*
Thought Leader Theater

WEDNESDAY May 9

8:30 a.m.–5:00 p.m.
Collegiate Wind Competition Turbine Testing
W375 Ballroom

2:00 p.m.–2:25 p.m.
Mapping the Market Potential for Behind-the-Meter Distributed Development in New York, Minnesota, and Colorado
Ian Baring-Gould, *Technology Deployment Manager, NREL*
Thought Leader Theater

2:45 p.m.–3:45 p.m.
Addressing Wind Deployment Challenges: Paths to Success by the Department of Energy's Regional Wind Resource Centers
Ian Baring-Gould, *Technology Deployment Manager, NREL*
Thought Leader Theater

Jobs for Rural America: The Ripple Effect from Wind Energy Development in Local Communities
Suzanne Tegen, *Wind Power Technology Engineering and Deployment Manager, NREL*
Thought Leader Theater

4:00 p.m.–4:25 p.m.
The Use of Dynamic Line Ratings in Control Rooms: The Final Step To Apply Wind-Cooling Effect
Charlton Clark, *Program Manager–Grid Integration, DOE*
Tech Station

4:30 p.m.–6:00 p.m.
Poster Reception
West Hall

Using Lessons Learned from Adjacent Industries for Wind-Wildlife Operational Challenges
Elise DeGeorge, *Senior Project Leader, NREL*

The Economy-Wide Impacts of High Wind Penetration Scenarios
Stuart Cohen, *Electric System Modeler, NREL*

Bridging the Gap Between Wind Energy Candidates and Companies
Suzanne Tegen, *Wind Power Technology Engineering and Deployment Manager, NREL*

Effects of High Wind Futures on Energy Prices
Joachim Seel, *Scientific Engineering Associate, LBNL*

Physical and Electrical Impacts to Nearby Facilities by Applying Dynamic Line Ratings
Bishnu P. Bhattarai, *Idaho National Laboratory (INL)*

Benefit of Computational Fluid Dynamics Data in Dynamic Line Rating Calculations
Alexander Abboud, *Research Scientist, INL*

Utilizing a Highly Resolved Forecasting Model Coupled with Computational Fluid Dynamics
Alexander Abboud, *Research Scientist, INL*

THURSDAY May 10

7:30 a.m.–3:00 p.m.
Collegiate Wind Competition Make-Up Turbine Testing
W375 Ballroom

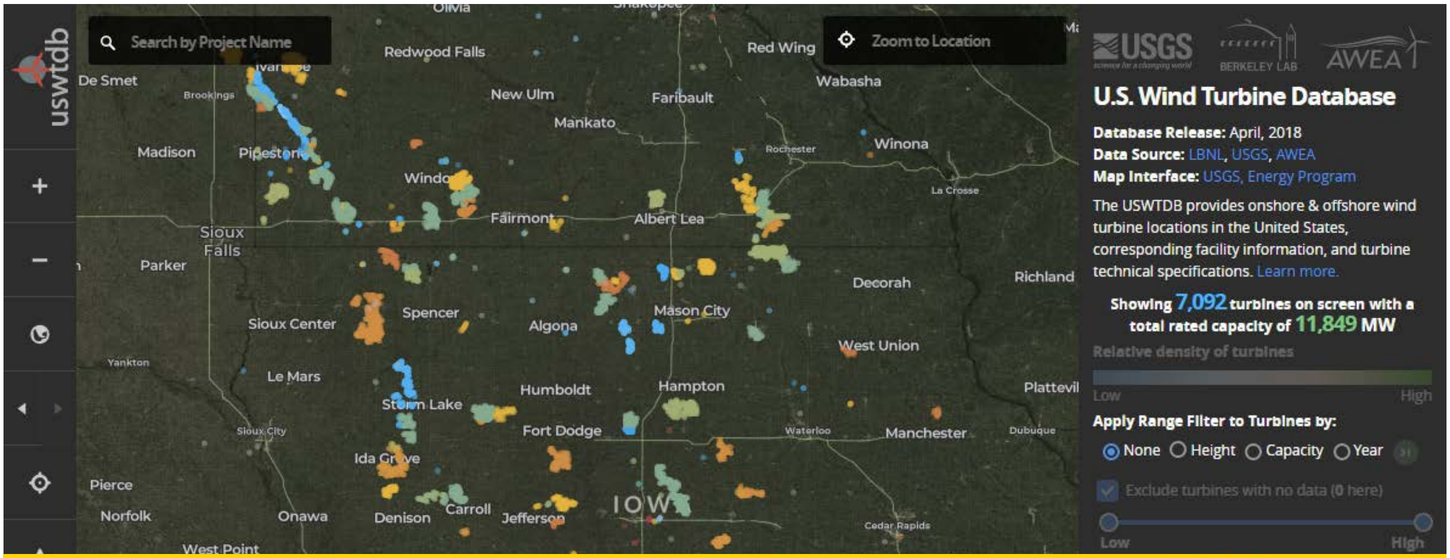
9:00 a.m.–10:15 a.m.
Collegiate Wind Competition Student Presentations
Front of Exhibition Hall

10:00 a.m.–10:25 a.m.
Analyzing Storage for Wind Integration in a Transmission-Constrained Power System
Jennie Jorgenson, *Engineer, NREL*
Thought Leader Theater

10:30 a.m.–10:55 a.m.
Impacts of Wind Energy on Wholesale Electricity Prices, Bulk Power System Operations, and Thermal-Plant Retirements
Ryan Wiser, *Senior Scientist, LBNL*
Project Development Station

11:00 a.m.–12:30 p.m.
Collegiate Wind Competition Team Expo
Front of Exhibition Hall

3:30 p.m.–4:30 p.m.
Collegiate Wind Competition Awards Ceremony
W375 Ballroom



The United States Wind Turbine Database contains nearly 60,000 turbines in more than 1,700 wind power projects spanning 43 states, Puerto Rico, and Guam. *Database screen capture by Ben Hoen, LBNL*

Massive U.S. Wind Turbine Data Set Released for Public Use

A comprehensive, regularly updated data set of U.S. wind turbine locations and characteristics is now publicly available. The United States Wind Turbine Database (USWTDB) currently contains nearly 60,000 turbines, constructed from the 1980s through 2018, in more than 1,700 wind power projects spanning 43 states plus Puerto Rico and Guam. The data set details turbines smaller than 30 meters, with capacities less than 70 kilowatts (kW), to turbines towering 181 meters (593 feet), with capacities of 6 megawatts (MW). The data cover not only land-based turbines, but also offshore installations.

The USWTDB was developed in 2017 with DOE support under a partnership among LBNL, the United States Geological Survey, and AWEA. This joint product is more comprehensive, accurate, and regularly updated than each individual organization's proprietary wind turbine data sets.

Since early 2017, the USWTDB has been used by the Departments of Defense and Homeland Security and the National Oceanic and Atmospheric Administration (NOAA) to perform crucial operational impact assessments of turbines on radar.

"The USWTDB directly supports the North American Aerospace Defense Command's air defense mission by enabling us to conduct credible and meaningful analysis of wind turbine-radar interference impacts and ultimately helps ensure that U.S. renewable energy does not adversely impact our ability to conduct our homeland defense mission," said Major-General Christopher Coates, North American Aerospace Defense Command director of operations.

Now, these same data can be accessed by researchers and the public via an online portal: the USWTDB Viewer.

Examples include studying wind energy-wildlife interactions, reviewing economic impact assessments of wind energy's deployment, examining the role of wind energy in the U.S. electric grid, predicting future deployment patterns, and better understanding wind deployment in one's local geography.

The data set includes not just the location of the turbines, but characteristics of each turbine, such as the make and model, total height, hub height, rotor diameter, the year of installation, and rated capacity to produce electricity.

This public-private partnership has allowed the individual organizations to combine their large proprietary turbine data sets with those of the Federal Aviation Administration. Many of these data have been vetted numerous times by multiple institutions and, therefore, are already of high quality in addition to the comprehensive quality control to ensure the data are as accurate as possible.

The USWTDB Viewer, the development of which was led by the United States Geological Survey Eastern Energy Resources Science Center, is unprecedented in its ability to search and sort the U.S. wind turbine fleet. Users can interact with the data using multiple filters and colorings to allow wind projects across counties, states, or regions to be quickly scanned for unique qualities. The full data set can be downloaded in a variety of formats, and users can connect to the underlying data via web services incorporating the Viewer into their own website.

The data set may be found at *https://eerscmap.usgs.gov/uswtdb/data/* and the Viewer at *https://eerscmap.usgs.gov/uswtdb/viewer*

Wind Project Neighbor Attitudes Mostly Positive, National Survey Reveals

A study led by Lawrence Berkeley National Laboratory (LBNL) provides unprecedented insight into the attitudes of Americans who live near U.S. wind turbines. The *National Survey of Attitudes of Wind Power Project Neighbors* study involved a collaboration among four universities, one consultancy, and two DOE research laboratories—LBNL and NREL. The research was based on a 2015–2016 effort that collected data from 1,705 individuals in 24 states living within 5 miles of 250 large-scale U.S. wind power projects (although most individuals lived within just one-half mile of turbines).

The research was broken down into four separate areas: (1) overall analysis of attitudes across 1,700 wind power project neighbors, (2) fairness of and attitudes toward wind power project-planning processes, (3) predicting audibility and resulting annoyance from wind power project sounds, and (4) a comparison of strongly annoyed individuals living near U.S. turbines who have physical or mental symptoms to individuals living in similar situations in Europe.

A survey led by LBNL researchers found that more than half of respondents felt positive toward their local wind facility. *Photo by Dennis Schroeder, NREL 30585*

The researchers found that more than half of respondents were positive toward their local wind facility, even when the respondents were limited to those within one-half mile of the turbines. However, the team also found that a significant minority of those living close to turbines had negative attitudes toward the projects, indicating opportunities for improvement in the development process.

Compensation is one such potential improvement. However, Ben Hoen, a research scientist at LBNL and the project lead, said, “It appears compensation is not a panacea. Those individuals who are receiving compensation are generally more positive than the rest of the population but, interestingly, not dramatically so. We found that other aspects of development are more important for neighbors.”

The research suggests, for example, that attitudes can be strongly tied to whether the respondent could see or hear the turbines from his or her home. Specifically, if the turbine sounds were perceived as annoying and/or the respondent did not believe the turbines fit within the local landscape, his or her attitudes were strongly more negative.

Further, perceptions surrounding the planning and development process were found to strongly correlate with existing attitudes. If the developer was perceived as fair and transparent and the respondent felt he or she had an opportunity to influence the outcome of the project’s planning, attitudes toward the turbines were significantly more positive. Several of the projects around which the respondents live were built many years ago, suggesting that attitudes remain entrenched long after the turbines are erected and that focusing on the planning process could help improve development outcomes.

A final area of research focused on “strongly annoyed” individuals—approximately 1% of the sample—who reported physical or mental symptoms related to the turbines. The most powerful correlate of being strongly annoyed was, again, perception of the planning and development process. The more fair the process was perceived to be, the less likely the respondent was to report having health symptoms related to the turbines.

Wind energy practitioners can use these results to tailor their development efforts and improve outcomes for the communities in which future wind energy is being considered.

See the report and a full list of researchers involved in the project at *https://emp.lbl.gov/projects/wind-neighbor-survey*

Competitiveness Improvement Project Hits First Certification Milestone

Primus Wind Power, which received a turbine testing program award under WETO’s Competitiveness Improvement Project (CIP) for distributed wind energy, achieved certification in February 2018 of its Primus Air40 wind turbine model. This certification represents just one of many successes achieved by CIP awardees.

Turbine certification requires third-party verified structural review and testing for safety and function, performance, and durability to national standards. Certification of wind turbines helps consumers identify products that have proven performance and filter out untested products and exaggerated marketing claims.

Primus Wind Power is a leading supplier of micro wind turbines, providing off-grid turbines with peak power of 160 and 400 watts. Primus’ turbines are typically installed to power remote assets that are not connected to a central electricity grid (e.g., oil and gas platforms, telecom towers, homes, and military equipment). Additionally, Primus is conducting certification testing of its Air30 model with support awarded under CIP.

CIP aims to facilitate the development of next-generation, U.S. manufactured small and mid-size wind turbine technology by awarding cost-shared contracts for system design optimization, advanced manufacturing, and turbine testing. In addition to Primus, CIP solicitations have resulted in numerous success stories, which are detailed in a new program fact sheet at *energy.gov/eere/wind/downloads/distributed-wind-competitiveness-improvement-project-fact-sheet*.

DOE-Funded Wind Profilers Feed National Weather Forecasts

As the contribution of wind energy to overall U.S. electricity generation grows, so does the importance of accurate forecasts for wind power production. These forecasts help maintain stability in the electrical grid and keep power costs low.

Through a collaboration between DOE and NOAA, three new wind measurement systems on the Pacific Coast are helping improve wind forecast accuracy. Following 2 years of successful operations, the systems officially transferred to NOAA in November 2017.

Deployed by researchers from Pacific Northwest National Laboratory (PNNL) and NOAA, each system consists of several components. A wind profiler—a type of radar—obtains measurements of wind speed and direction up to 5 miles into the atmosphere. The profiler is surrounded by a radio-acoustic sounding system that adds temperature measurements up to 1.8 miles. An adjacent meteorological station collects standard weather data, such as surface wind speed and wind direction, pressure, and humidity. Together, the equipment provides a "vertical profile" of weather conditions in the area.

A previous DOE study conducted in the Midwest established that additional wind data to initialize the forecast models greatly improved their accuracy. Because weather systems generally move from west to east, the new systems were sited on the coast in Forks, Washington, and Astoria and North Bend, Oregon.

Data are compiled hourly and made available on NOAA's Meteorological Assimilation Data Ingest System. Anyone can access the data, but it's especially useful for NOAA's National Weather Service, which relies on data from across the county to feed its regional forecast models.

Spaced about 155 miles apart, the new systems complement an existing network of coastal profiling radars in California. This "picket fence" closes a gap in model boundary conditions along the West Coast.

On this new wind profiler, an array of 26 antennae on the platform operate in series to measure wind speed and direction up to 8 kilometers high. This system is located at the small regional airport in Astoria, Oregon. *Photo courtesy of Clark King, NOAA Earth System Research Laboratory/Physical Sciences Division*

The new systems also contributed to another recently completed DOE field study in the Columbia River Gorge region of Oregon and Washington. That effort focused on collecting wind data to improve the underlying physics algorithms in forecast models.

Fed into forecast models, the wind profiler data can help energy planners determine whether they should buy more wind or use other energy sources. The publicly available data can also be used for research that will eventually benefit the wind industry.

For more information, visit the DOE website at *https://a2e.energy.gov/projects/cwp* or see the real-time data at *http://www.esrl.noaa.gov/psd/data/obs/datadisplay/*

On-Site Research To Determine Causes of Premature Drivetrain Gearbox Failure

Although wind energy costs have declined over the past two decades, premature drivetrain failure still can lead to higher-than-expected turbine operation and maintenance (O&M) costs. To help identify the causes of premature failures and ultimately reduce the costs of wind energy, NREL's Drivetrain Reliability Collaborative is investigating operational conditions most likely to cause drivetrain failures.

As part of this research, NREL researchers recently installed a new gearbox and main bearing in the DOE-owned GE 1.5-MW wind turbine at the NWTC. Researchers will be assessing the Winergy 4410.4 gearbox and SKF SRB-Wind

Installation of the drivetrain as part of the new Drivetrain Reliability Collaborative study to determine the causes of premature gearbox and main bearing failure. *Photo by Jonathan Keller, NREL 49494* main bearing to understand the true operating conditions of the turbine's drivetrain.

Researchers placed instrumentation within the Winergy gearbox to help understand the causes of bearing axial cracking, which can dramatically shorten the lifespan of turbine bearings. The main bearing is instrumented to help analyze the causes of main bearing micropitting and progressive wear. Both conditions can lead to premature drivetrain failure, which increases the wind industry's O&M costs.

"Failures of gearbox bearings by axial cracking and of main bearings by premature wear are leading to excessive O&M costs for wind plant operators and a higher levelized cost of energy," NREL Researcher Jon Keller said. "This DOE-laboratory-industry validation campaign utilizes the world-class National Wind Technology Center resources to reduce premature failures and related O&M costs."

The NWTC provides unique atmospheric conditions—in particular, high winds—that make the site ideal for this kind of drivetrain validation. In addition, NREL's controllable grid interface allows researchers to examine how grid conditions and faults affect drivetrain loads.

NREL's research is expected to last through spring. Insights gained during this period could potentially enable improvements to gearbox and bearing components or reduce the damaging effects of the turbine's reaction to severe atmospheric and grid conditions.

First-of-Its-Kind Report Benchmarks Costs for U.S. Small Wind Projects

A recent PNNL report, *Benchmarking U.S. Small Wind Costs*, located at https://wind.pnnl.gov/pdf/Benchmarking_US_Small_Wind_Costs_092817_PNNL.pdf, is the first of its kind to benchmark costs for small wind projects installed in the United States. The report provides a starting point to help expand the U.S. distributed wind market by identifying potential opportunities to reduce costs and providing a benchmark to track cost-reduction progress.

To set the benchmark, the report summarizes cost information from 70 projects (57 residential systems and 13 commercial systems) using 10 turbine models in 16 states. The total capacity of the systems analyzed amounts to 1.5 MW. The team found that the average cost of a representative residential system was $11,953/kW, whereas a commercial system costs, on average, $7,389/kW.

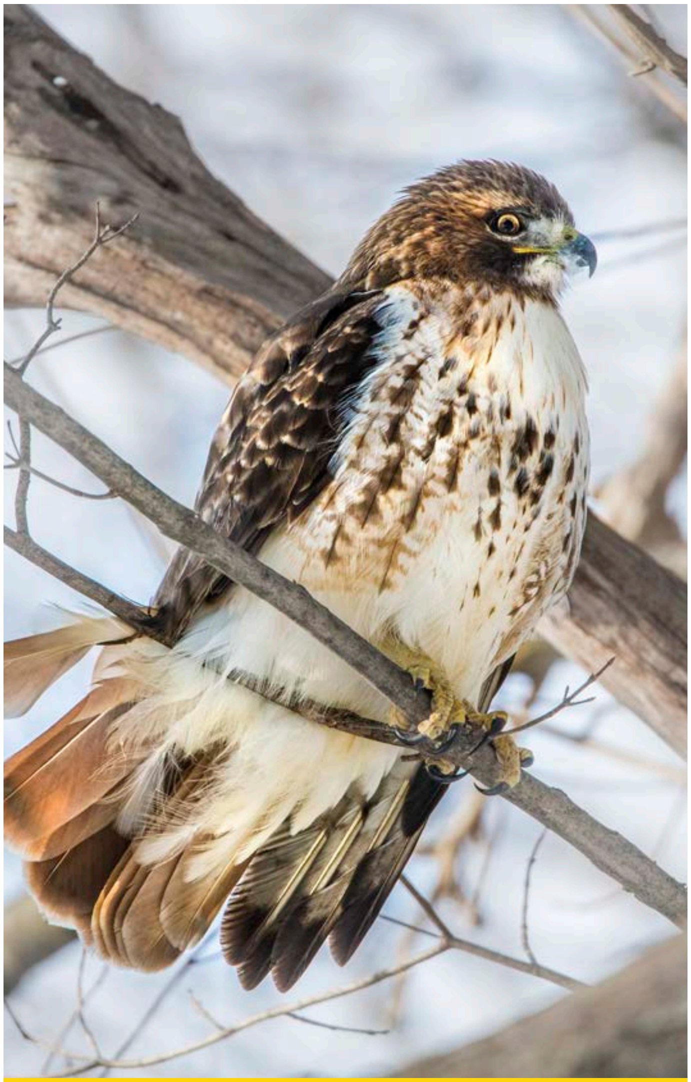
With funding from WETO, researchers at PNNL have been studying the distributed wind market and associated, often high costs of deploying wind technology. Distributed wind power is used at or near where it is generated, as opposed to wind power from wholesale generation, where power is sent to consumers via transmission lines and substations. Distributed systems can range in size from a 5-kW turbine powering a home to a multimegawatt turbine providing electricity to a manufacturing facility.

Additional distributed wind work conducted recently by PNNL includes holding a Distributed Wind Workshop for federal agencies in February. This workshop was designed to educate federal agency stakeholders about distributed wind, its potential applications, the economics of wind projects, and how to deploy distributed wind at federal sites.

PNNL also produces the yearly *Distributed Wind Market Report,* located at energy.gov/windreport, which has become a go-to resource for the wind industry. The report provides a year-to-year comparison of growth and trends, including costs, number of deployments, performance and capacity factors, types of turbines used, customer type, domestic and international markets, and market drivers and barriers.

Pooling Our Knowledge and Protecting Wildlife with Adaptive Management

Wind energy development projects continue to improve their practices through lessons learned and better understanding the outcome of management decisions, especially with wind and wildlife impacts. The process of adaptive management (AM) is of increasing interest worldwide. The practice is being considered for the wind industry to employ a learning-based management approach to reduce scientific uncertainty.



Hawks like this one are benefiting from new adaptive management measures across the globe. *Photo courtesy of Montanus Photography*

While environmental reviews of wind projects may be extensive, sometimes impacts are apparent only after the turbines are spinning. Adaptive management means keeping close watch on wind farms and pooling data to inform other projects around the globe.

Implementing AM has the potential for impressive results—reduced deaths of raptors in Spain, new measures to protect eagles in Norway, and less risk to hen harriers in the United Kingdom. It is an international effort that also furthers cooperation and teamwork.

While ultimately the practice has potential benefits, practical and economic challenges can arise from mandated AM regimes. Adaptive management has the potential to add uncertainty surrounding monitoring and mitigation requirements that may affect variables, such as project financing. In the United States, some wind farms are working to address this by developing tiered AM plans that lay out actions that will be taken if impacts exceed expected levels.

PNNL scientist Andrea Copping is one of the lead authors of a recent white paper that explores the benefits and challenges of AM applied to wind energy.

“The concept grew out of the United States, but we learned immediately that while other countries said they were not familiar with the term adaptive management, they were actually applying many of the principles,” said Copping. “We can learn from every project. Perhaps the unintended consequences a wind operator addresses will help the next project in its planning stages.”

“If you are creating a single wind farm, what you learn can benefit not only your site. It may also benefit wind farms across the landscape if we pool what we are learning,” she added.

In Spain, stakeholders used the approach to monitor the behavior of raptors near wind farms; the insights cut in half the number of collisions with just a small reduction in energy production. In the United Kingdom, monitors found that hen harriers were much more likely to populate the fields around wind turbines after the fields are mowed. That finding resulted in a modified mowing schedule to reduce bird blade strikes, and it also provides important information about the siting of future turbines.

The white paper, sponsored by Working Together to Resolve Environmental Effects of Wind Energy (WREN), includes authors from PNNL, the Bureau of Ocean Energy Management, Marine Scotland Science, the Norwegian Institute for Nature Research, DOE, and the Berlin Institute of Technology.

Copping helps lead a group of wind energy stakeholders from 11 nations who meet regularly through WREN. WREN, an initiative under the International Energy Agency Wind Committee, is supported by DOE's Tethys Knowledge Management System located at https://tethys.pnnl.gov

You can find the full text of the *Adaptive Management White Paper* online on WREN Hub at https://tethys.pnnl.gov/content/wren-adaptive-management-white-paper

New Software Tool Boosts Utility Transmission Capacity

A wind plant study initiated in 2010 by Idaho National Laboratory (INL) and WETO sought to explore how transmission lines, when cooled by the wind, are capable of handling more electricity. The research resulted in the development of a new software tool: General Line Ampacity State Solver (GLASS), which offers the ability to blend data from weather monitors and electric utility systems with weather analysis algorithms enhanced by computational fluid dynamics (CFD).

Power transfer capacity is affected by stability, voltage limits, and thermal ratings, with the last representing the greatest opportunity to quickly, reliably, and economically improve the grid's capacity. INL's wind power team surmised that if they could come up with a reliable system for dynamic line rating to replace the conservative static line ratings in use, system planners and grid operators might have access to greater transmission capacity.

The first step was to find a CFD software program that could be integrated and tested against actual wind and weather station data. Coordinating with a CFD program from WindSim, the INL team developed GLASS.

Since 2010, INL has collaborated with Idaho Power Company on dynamic line rating concepts and recently finished a full instrumentation of two test beds with weather stations and line rating software in Idaho. INL also completed a cooperative research and development agreement with AltaLink LLC—Alberta, Canada's, largest regulated electric transmission company—on a field study of four transmission line segments in support of a wind project's expansion request.

"From what we've seen, it's working," said Phil Anderson, project leader for Idaho Power. "Our greatest challenge was to come up with a standard design that didn't cost a fortune." With GLASS, Idaho Power has been gathering weather data and calculating steady-state, transient, and what INL calls "true dynamic line rating" ampacities (ampacity is the amount of current a line can carry). The next step is ramping up the software to calculate forecasted line ampacities and temperatures. "It really shows the viability of weather-based dynamic line rating," Anderson said.

While WindSim was originally a software program designed to optimize placement and performance of wind turbines, the company's collaboration with INL has allowed the company to broaden its solutions, according to Catherine Meissner, WindSim's software development manager. "The next current challenge is de-risking the path to market and deployment," she said.

In 2018 and 2019, INL plans to refine the GLASS software with another industry partner, testing endurance and commercialization possibilities.

A recently published NREL guide addresses the mitigation of risk related to investment and financing of wind energy projects. *Photo by Dennis Schroeder, NREL 20878*

Guide to Wind Development Financing Designed To Increase Investment Pool

The numbers speak for themselves. Investment in U.S. wind energy has averaged nearly $13.6 billion annually since 2006, totaling more than $140 billion—demonstrating wind energy's persistent appeal and its increasing role in the U.S. electricity generation portfolio.

And yet, some investors still consider wind energy a specialized asset class. To address this, NREL is leading an effort called Performance, Risk, Uncertainty, and Finance, or PRUF. PRUF focuses on the mitigation of risk related to investment and financing of wind energy projects.

As part of the PRUF initiative, NREL researchers published *Wind Energy Finance in the United States: Current Practice and Opportunities*, located at *https://www.nrel.gov/docs/fy17osti/68227.pdf*, a representative and wide-ranging resource for the wind development and financing processes. The publication provides an overview of the wind project development process, capital sources, and common financing structures, as well as traditional and emerging procurement methods.

The report also provides a high-level demonstration of how financing rates impact a project's overall cost of energy and its cost competitiveness with other investment alternatives.

Through activities such as PRUF and general industry maturation, a broad and widely understood assessment of wind energy project risk among developers, investors, and policymakers can help to expand the potential pool of industry investors and drive down the cost of capital for the wind industry. Reducing the cost of capital can lead to reductions in the levelized cost of energy, which in turn contributes toward wind energy competitiveness in the marketplace.

Clemson University To Test Next-Generation Wind Drivetrain

Last fall, wind turbine manufacturer MHI Vestas announced a $35 million, 5-year investment with Clemson University to test its new 9.5-MW gearbox at Clemson's SCE&G Energy Innovation Center in Charleston, South Carolina. The gearbox is for MHI Vestas's new 9.5-MW offshore wind turbine, which has a rotor diameter of 164 meters (over 500 feet) and will be the most powerful wind turbine in the world.

The partnership between Clemson University and MHI Vestas to test the drivetrain over a period of several years marks the achievement of DOE's goal to establish a U.S. testing facility for both land-based and offshore wind development in the United States.

In November 2009, DOE provided Clemson University's Restoration Institute a $45-million financial-assistance award funded through the Recovery Act to design, build, and operate a facility to test next-generation wind turbine drivetrain technologies. The university matched the grant with $53 million in public and private funds and developed the Energy Innovation Center, which can test wind turbine drivetrains on two dynamometer test rigs: 7.5 MW and 15 MW in capacity rating.

MHI Vestas is focused on designing, manufacturing, installing, and servicing offshore wind turbines. Vestas, a Danish company committed to the U.S. marketplace, currently has three manufacturing plants in Colorado. The joint venture company will now test its large drivetrain, intended for offshore wind development, over an extended period of years utilizing the 15-MW test stand. Dynamometer test rig modifications and equipment installation are currently underway. The planned testing will allow MHI Vestas to

MHI Vestas will be the first company to test a next-generation drivetrain on the 15-MW dynamometer test stand at Clemson University's SCE&G Energy Innovation Center, shown here. The facility is specifically designed for large-component testing and utility-scale validation. *Photo courtesy of Clemson's SCE&G Energy Innovation Center* measure how the 9.5-MW gearbox and bearings will react over the course of a 20-year wind turbine lifespan. By collecting and analyzing the test data, the company said it will be able to optimize a service strategy for the turbine with the goal of reducing the levelized cost of electricity for offshore wind, while establishing a supply chain for the emerging U.S. offshore wind industry.

While MHI Vestas will be the first company to test a next-generation drivetrain on the 15-MW test stand, Clemson is partnering with General Electric (GE) to test wind turbine drivetrains using the 7.5-MW test stand. The third GE turbine drivetrain is now on Clemson's 7.5-MW test stand.

Additionally, Clemson and DOE invested in an eGRID research facility to provide up to 20 MW of tailored electrical power for equipment testing. The research grid may operate at various voltages and frequencies, allowing testing of equipment from around the world. This capability allows turbine manufacturers to test the grid resilience and reliability of turbines by simulating grid faults and grid voltage scenarios in a laboratory setting.

Wind's Near-Zero Cost of Generation Impacting Wholesale Electricity Markets

Wind generation can create exciting opportunities and interesting challenges when integrating large quantities of energy into the electric grid. Wind's near-zero marginal cost of generation in particular is noticeably impacting competitive wholesale electricity markets in the United States and around the world. In a recent article published in *The Electricity Journal*, researchers from Argonne National Laboratory (ANL) reviewed a range of market mechanisms that are currently being used to ensure long-term reliability in electricity systems with increasing quantities of wind generation.

"The emergence of wind, solar, storage, and distributed resources in modern power systems has made it increasingly important for markets to adequately compensate the diverse set of attributes that provide value to the system," said ANL Researcher Todd Levin, one of the co-authors of the study. To quantify the cost and reliability impacts of these different market designs, the ANL team is now conducting original modeling studies based in part on the findings from this study.

Most wind generation costs are incurred either during construction or ongoing maintenance, so once a unit is in operation, there is essentially no cost associated with producing each megawatt-hour of electricity. As a result, increasing wind penetrations tend to drive down wholesale electricity prices in competitive markets, prices that thermal (coal, nuclear, and natural gas) power plants traditionally rely on to provide the bulk of their revenues. This effect can be caused by other technologies as well. In fact, the 2017 DOE *Staff Report to the Secretary on Electricity Markets and Reliability* found that low natural gas prices have been the primary contributor to wholesale price reductions in recent years. Thanks to its low marginal cost, wind generation also tends to displace generation from thermal plants, reducing their output levels and associated revenues from electricity sales. As these effects become more pronounced, it is likely that they will increasingly affect decisions by investors and owners to construct new or retire existing thermal plants.

While market signals may prompt unprofitable resources to exit the market, excessive retirements may cause supply shortages during periods when demand is high or wind generation is low, leading to deterioration of system reliability. As a result, new market design mechanisms are continually being explored to ensure that individual generation units earn adequate compensation for their contribution to system stability and reliability, which will ultimately help enable higher levels of wind generation.

A capacity market is one such mechanism that has been implemented in four U.S. electricity markets to ensure that sufficient generation capacity is available to meet future demand. Capacity markets provide generators with an additional revenue stream for being available to reliably generate electricity during periods of peak demand, regardless of whether they are called upon to generate. The ANL research highlights the differences in market rules

A recent ANL journal article studies U.S. capacity markets and finds that electricity market design must continue to evolve to achieve cost-effective policies for resource adequacy. *Photo by Al Puente, NREL 01308*

across each of the four U.S. centralized capacity markets, how these market rules are currently supporting long-term system reliability, and how the rules may need to evolve in the future as wind (and solar) penetrations continue to increase. Specifically, this study reviews differences in how each market determines its need for capacity and suggests that the resulting capacity demand curves should be benchmarked more closely to the incremental reliability value of additional capacity.

The study also analyzes performance incentives in the four existing capacity markets and identifies substantial differences in how capacity credits for wind power and energy storage are determined. Finally, a review of outcomes from capacity market auctions reveals a large variability in capacity prices over time and between the different markets.

"Our review indicates that current capacity markets are somewhat divergent and not well understood," said co-author and ANL Researcher Audun Botterud. "They need to evolve further to ensure that capacity adequacy is achieved in a cost-effective manner, particularly in light of the changing resource mix."

See *The Electricity Journal* article at *http://www.sciencedirect.com/science/article/pii/S1040619017303330*

WIND INDUSTRY EVENTS

2018 Alaska Regional Energy Workshops—Kodiak
May 15–16, 2018
Kodiak, Alaska

New England Energy Conference and Exposition
June 4–5, 2018
Falmouth, Massachusetts

U.S. Offshore Wind Conference & Exhibition
June 7–8, 2018
Boston, Massachusetts

American Meteorological Society 23rd Symposium on Boundary Layers and Turbulence
June 11–15, 2018
Oklahoma City, Oklahoma

ESIG 2018 Forecasting Workshop
June 19–21, 2018
Saint Paul, Minnesota

Wind-Wildlife Technology Development and Innovation Open House
June 20–21, 2018
Boulder, Colorado

AWEA Regional Wind Energy Conference 2018–Northeast
June 26–27, 2018
Portland, Maine

2018 REcharge Academy
July 23–27, 2018
Harrisonburg, Virginia

IEEE Power & Energy Society General Meeting
August 5–9, 2018
Portland, Oregon

Wind Resource & Project Assessment Conference
September 11–12, 2018
Austin, Texas

Offshore Wind Executive Summit
September 13–14, 2018
Houston, Texas

Wind Energy Finance & Investment Conference—East
October 1–2, 2018
New York, New York

ESIG 2018 Fall Technical Workshop
October 1–3, 2018
Denver, Colorado

Wind Energy Finance & Investment Conference—West
October 5, 2018
San Francisco, California

The Composites and Advanced Materials Expo
October 15–18, 2018
Dallas, Texas

AWEA Offshore WINDPOWER 2018 Conference
October 16–17, 2018
Washington, D.C.

AWEA Wind Energy Fall Symposium 2018
November 13–15, 2018
Colorado Springs, Colorado

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For more information, visit:
energy.gov/eere/wind/wind-rd-newsletter

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