NREL
Transforming ENERGY

Accomplishments & Mid-Year Performance REPORT

WIND ENERGY PROGRAM: FISCAL YEAR 2020

Through transformative science and innovation, the U.S. Department of Energy's (DOE's) National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory's (NREL's) Flatirons Campus helps lead the way to a sustainable energy future that powers America with significant levels of reliable, low-cost, and accessible wind energy

Since 1976, NREL has provided an ideal environment for the research and development (R&D) of advanced energy technologies through:

- Wind energy resource assessments
- World-class research facilities
- High-performance computing and modeling
- Data and technology analysis
- Manufacturing breakthroughs
- Environmental analysis and wildlife conservation efforts
- Education and training programs for a future workforce.

These activities enable the innovations needed to advance U.S. wind systems, address market and deployment barriers, and drive down the cost of wind energy with more efficient, more reliable, and more predictable wind energy systems.

This report provides an overview of the achievements NREL delivered on behalf of DOE's Wind Energy Technologies Office (WETO) and other partners during the first and second quarters of Fiscal Year (FY) 2020.

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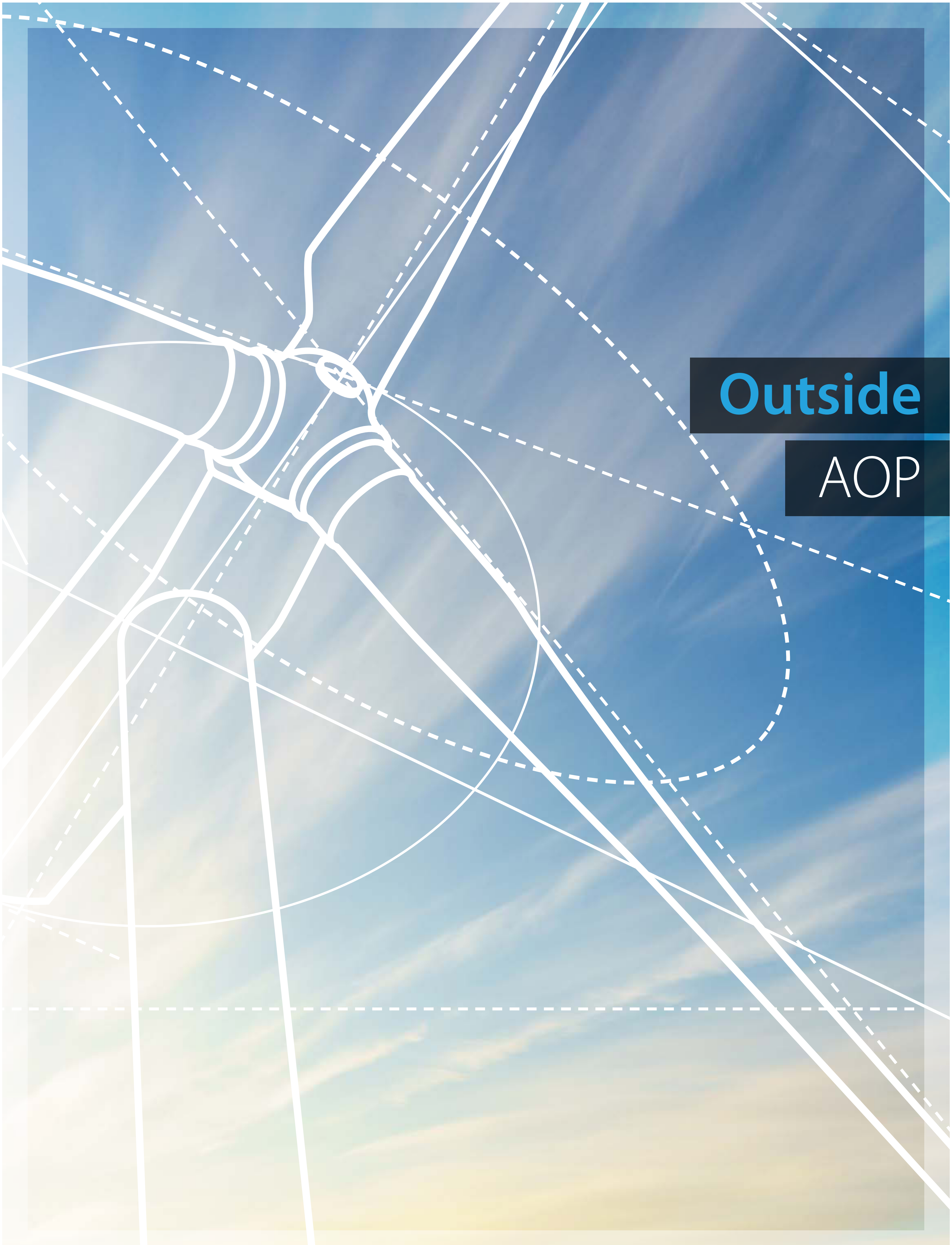

Wind Experts Write Book To Empower Development of Wind Plant System Models

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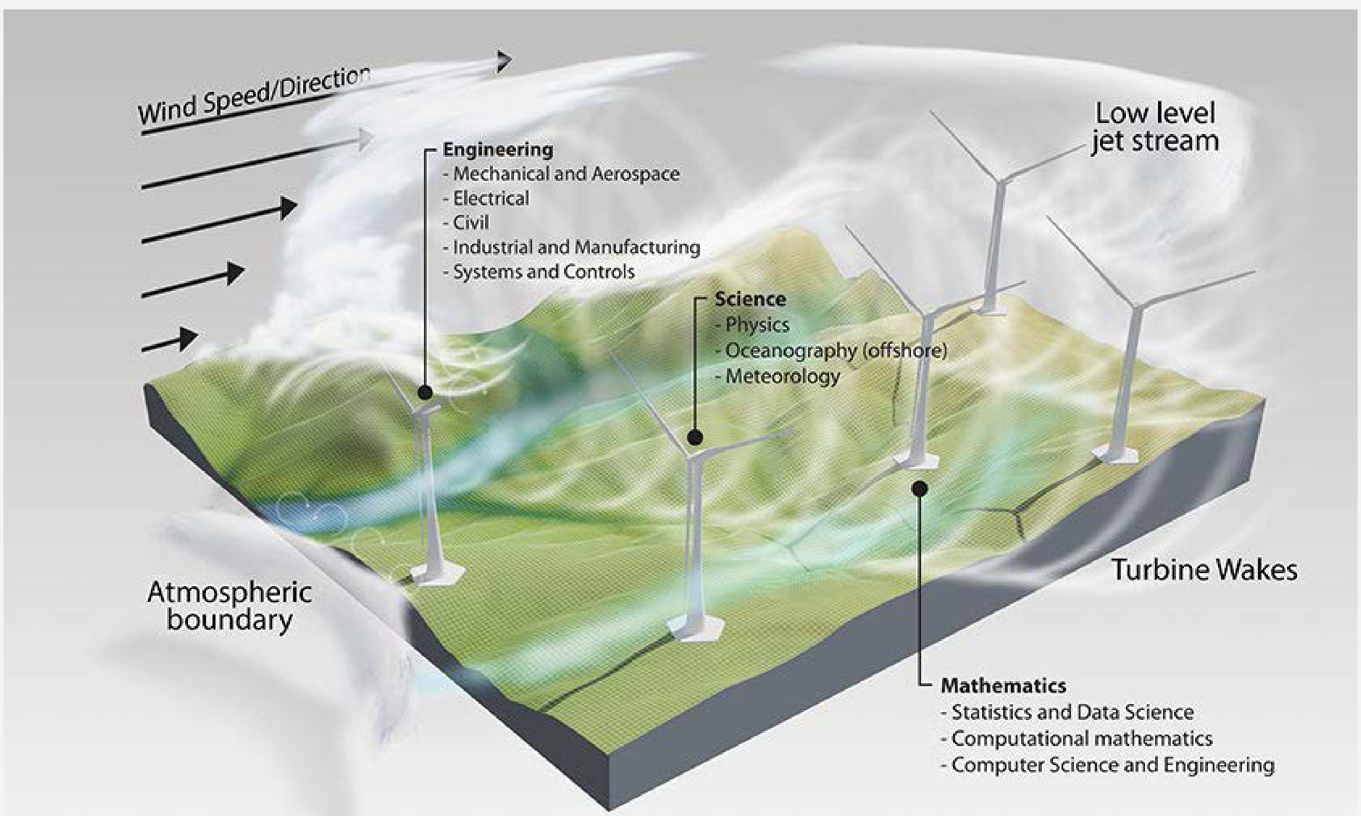
Along with several other technical experts across the world, the NWTC's Chief Engineer, Paul Veers, wrote a two-volume book titled, "Wind Energy Modeling and Simulation Volume 1: Atmosphere and Plant and Volume 2: Turbine and System," as an end-to-end resource, covering every aspect of wind energy design, modeling, and simulation. NREL contributed to 10 of the book's 18 chapters, helping to explain the principle elements behind multiple subsystem models that are needed to create a fully optimized wind power plant.

Significance and impact:

Written with plain-language explanations and mathematical examples, the book allows practitioners with atmospheric, aerospace, mechanical, electrical, and other scientific backgrounds to learn directly from internationally recognized wind experts, empowering these individuals to develop their own wind plant system models. By providing a common language and baseline level of knowledge across the international wind community, NREL researchers empower fellow wind energy practitioners to pursue larger and more efficient wind power modeling systems to make wind one of the world's primary sources of low-cost electricity generation.



Authors of "Wind Energy Modeling and Simulation, Volumes 1 and 2," use this illustration to explain how a spectrum of science, engineering, and mathematical disciplines can help make wind energy one of the world's primary sources of electric power generation. *Illustration by Josh Bauer, NREL*

NREL Secures Three Offshore Wind Turbine Research Projects, Helping Offshore Wind Deployment Set Sail

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NREL was awarded $5.7 million in new funding from DOE's Advanced Research Projects Agency-Energy (ARPA-E) for work in the field of floating offshore wind turbines. NREL was named prime contractor for three projects within ARPA-E's Aerodynamic Turbines Lighter and Afloat with Nautical Technologies and Integrated Servo-control (ATLANTIS) program to innovate floating offshore wind technologies.

Significance and impact:

More than 26,000 megawatts (MW) of planned offshore wind capacity exists in the offshore wind development pipeline, and forecasts show accelerated growth. Projects awarded to NREL ensure that innovative floating offshore wind technologies will continue to develop the technology required to access offshore wind deployments at depths greater than 60 meters (m)—the point at which fixed-bottom structures are no longer feasible. Accessing floating offshore wind resources at greater depths can significantly expand U.S. offshore wind capacity by tapping into copious amounts of quality wind resources that reside near population centers in coastal communities.

Shining (UV) Light on Inspired Innovation with Industry Partners

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For nearly 2 years, NREL researchers have supported a project that explores whether illuminating turbines with dim ultraviolet (UV) light will minimize bat impacts at wind energy power plants. But Scott Schreck, a systems design engineer from Siemens Gamesa Renewable Energy (SGRE), saw another potential application.

No off-the-shelf UV light fit the specifications Schreck required for development work at SGRE, so he reached out to NREL to see if he could use a custom-designed "bat light" for a wind tunnel trial to better illuminate air flow tufts. NREL contacted Dave Dalton from Bat Research and Consulting, who built the custom-designed bat lights and shipped SGRE an available unit.

Significance and impact:

The bat light presented several advantages for Schreck's wind tunnel application. The light enabled clearer visualization of the flow field, faster and more reliable interpretation of the results, and more efficient use of expensive wind tunnel evaluation time. Similar stories abound over the years as NREL serves as expert and liaison with a global network of experts across the energy industry.

SpiderFLOAT Spins Web of Innovation To Catch More Offshore Wind

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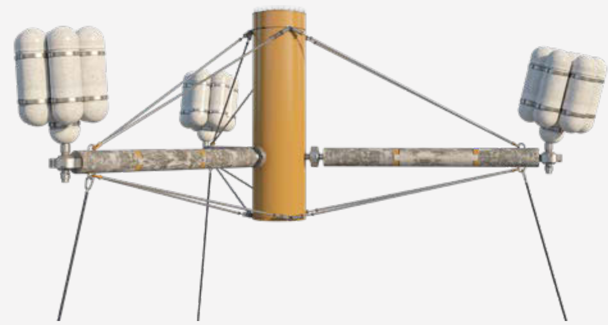
An NREL-developed scalable offshore floating wind system, dubbed "SpiderFLOAT" for the system's spider-like components, could help drive down the cost of deep-water wind energy. SpiderFLOAT challenges the existing paradigm of offshore energy production—historically influenced by oil and gas project design—by drastically reconceptualizing what's possible for an offshore wind platform and spinning a web of new innovations to accompany the system. Funds from the Technology Commercialization Fund and Energy I-Corps helped launch SpiderFLOAT as an internal NREL project before becoming part of DOE's ARPA-E ATLANTIS program to develop a 10-MW Ultraflexible Smart Floating Offshore Wind Turbine (USFLOWT).



Named for its spider-like appendages, SpiderFLOAT aims to reduce the cost of energy by combining SpiderFLOAT's scalable offshore floating wind substructure with a 10-MW reference turbine. *Illustration by Josh Bauer, NREL*

Significance and impact:

SpiderFLOAT's modular design means it can meet the needs of various offshore wind systems and make it possible to capture the planet's abundant deep-water wind resources more effectively, helping provide more low-cost wind energy to coastal communities.

NREL Models Predict Lower Costs for Floating Offshore Wind on Oregon Coast

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Funded by the Bureau of Ocean Energy Management (BOEM), the "Oregon Offshore Wind Site Feasibility and Cost Study" assesses the potential costs of floating offshore wind farms at least 10 nautical miles from Oregon's coast, where wind speeds are some of the world's strongest. The levelized cost of energy (LCOE) for the hypothetical projects—600 MW each, outfitted with 15-MW turbines, and developed by 2032—ranged from $74 per megawatt-hour (MWh) in the north to $53 per MWh in the south, near the California border.

An NREL model predicts floating offshore wind could unlock new regions to offshore wind development, such as the Oregon coast. *Photo by Senu Sirnivas, NREL 27606*

Significance and impact:

The model indicates the cost of deploying floating offshore wind in Oregon could be 30% to 40% less than previously estimated, which improves the prospects of offshore wind deployment in the region.

Flatirons Campus

Research Facilities

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Research Partnerships Provide Insight into Offshore Wind Blade Design and Improving Blade Service Life

This project maintains and operates wind research facilities at DOE's world-class Flatirons Campus wind research facilities, including the safe operation and maintenance of DOE's two 600-kilowatt (kW) Controls Advanced Research Turbines (CARTs). NREL completed two multiyear research partnerships with the University of Virginia, as well as the German Aerospace Center (DLR) and Fraunhofer Institute for Wind Energy Systems, to conduct full-scale wind turbine aerodynamics research experiments utilizing the two-bladed and three-bladed research wind turbines (CART2 and CART3).

The CART2 with the ARPA-E two-bladed flexible downwind rotor. *Photo by Lee Jay Fingersh, NREL 53511*

Significance and impact:

Funded by ARPA-E, the first project involved retrofitting DOE's CART2 with two highly flexible Segmented Ultralight Morphing Rotor blades designed in accordance with the objectives of the University of Virginia's project. Insights from the project helped solve two unique challenges to improving durability and reducing costs for offshore wind applications such as how offshore flexible blades can withstand strong, hurricane-force winds, and how these blades perform in a downwind configuration.

The second project was a research partnership with the DLR that used the CART3 to investigate how well rotor blades designed with bending-torsion coupling handle strongly variable wind speeds. Three 20-m-long blades were installed on the CART3, along with instrumentation that captured the structural-mechanical and aerodynamic behavior of the blades. At higher wind speeds, each rotor blade independently twisted to lessen the angle of attack and the lift generated by the airfoil, which reduces load on the system and increases rotor blade service life.

Installation of the DLR rotor on the CART3. *Photo by Lee Jay Fingersh, NREL 54232*

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Flatirons Investments Meet Future Grid Research Needs

This project supports the expansion of renewable energy research capabilities at DOE's Flatirons Campus to perform cutting-edge research on the performance, cost, reliability, sustainability, manufacturability, and resilience of complex hybrid energy systems. NREL invested in a second controllable grid interface (CGI), a device that provides system engineers with a better understanding of how wind turbines, photovoltaic inverters, and energy storage systems react to disturbances on the electric power system, which will enhance grid integration research. Construction of the 19.9-MW transmission interconnection, is nearing completion which, coupled with both the first and second CGIs, will improve grid integration research to reduce the cost of electricity and improve reliability of grid power supply.

Significance and impact:

Both developments improve grid integration research at the Flatirons Campus, and upgrading electrical power capacity to 19.9 MW enables future research initiatives that are aimed at ensuring reliability and resiliency of the U.S. power grid as increasing levels of megawatt-scale renewable energy generation and storage technologies are added.

Xcel Energy switchyard civil construction of the 19.9-MW interconnection on the Flatirons Campus. This interconnection further expands research capabilities by allowing researchers to see how grid technologies interact with the larger power grid. *Photo by Brian Cox, NREL*

Distributed Wind

Research & Development

Distributed Wind Research, Development, and Evaluation

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Competitiveness Improvement Project Helps Drive Innovation for Distributed Wind Technology

The Competitiveness Improvement Project (CIP) works with dozens of small businesses across the United States to make distributed wind technology mainstream. NREL issued a request for proposals soliciting projects that help make distributed wind energy cost competitive, improve its interoperability with other distributed energy resources, and increase the number of small- and medium-scale wind turbine designs certified to national testing standards.

Primus Wind Power has worked through the CIP program to continuously improve its Air series of wind turbines, including certification, design, and controller innovations. *Photo courtesy of Southwest Windpower*

Significance and impact:

CIP investments of $7.75 million have supported manufacturers of distributed wind turbines—typically small businesses—through competitively awarded, cost-shared funding. CIP-supported efforts result in cost reductions, more reliable technology, and consumer-friendly business models that enable U.S. leadership to supply distributed wind technologies in domestic and global markets. Further innovations will be possible by soliciting projects that can help increase the nation's capacity of distributed wind energy.

Tools Assessing Performance

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Researchers Identify Best Configuration for Modeling Wind Resource Across United States

As part of a multilab effort with Argonne National Laboratory, Los Alamos National Laboratory, and Pacific Northwest National Laboratory, NREL researchers performed a sensitivity study to identify the best parameters and inputs to conduct multiyear Weather and Research Forecasting (WRF) simulations across the contiguous United States, Hawaii, and Alaska.

Significance and impact:

The sensitivity study helped researchers evaluate model drift, boundary conditions, and other relevant inputs that impact WRF outputs, and subsequent analysis has identified the optimal input configurations to reduce bias in WRF simulation outputs. By identifying the optimal configuration for WRF simulation parameters and inputs, researchers can better meet the needs of the distributed wind industry with resource forecasts that more accurately estimate project performance and improve turbine reliability models. Developing these models will lead to significant reductions in the uncertainty of preconstruction turbine performance estimates, thereby reducing the risk perceived by the financial community and consumers.

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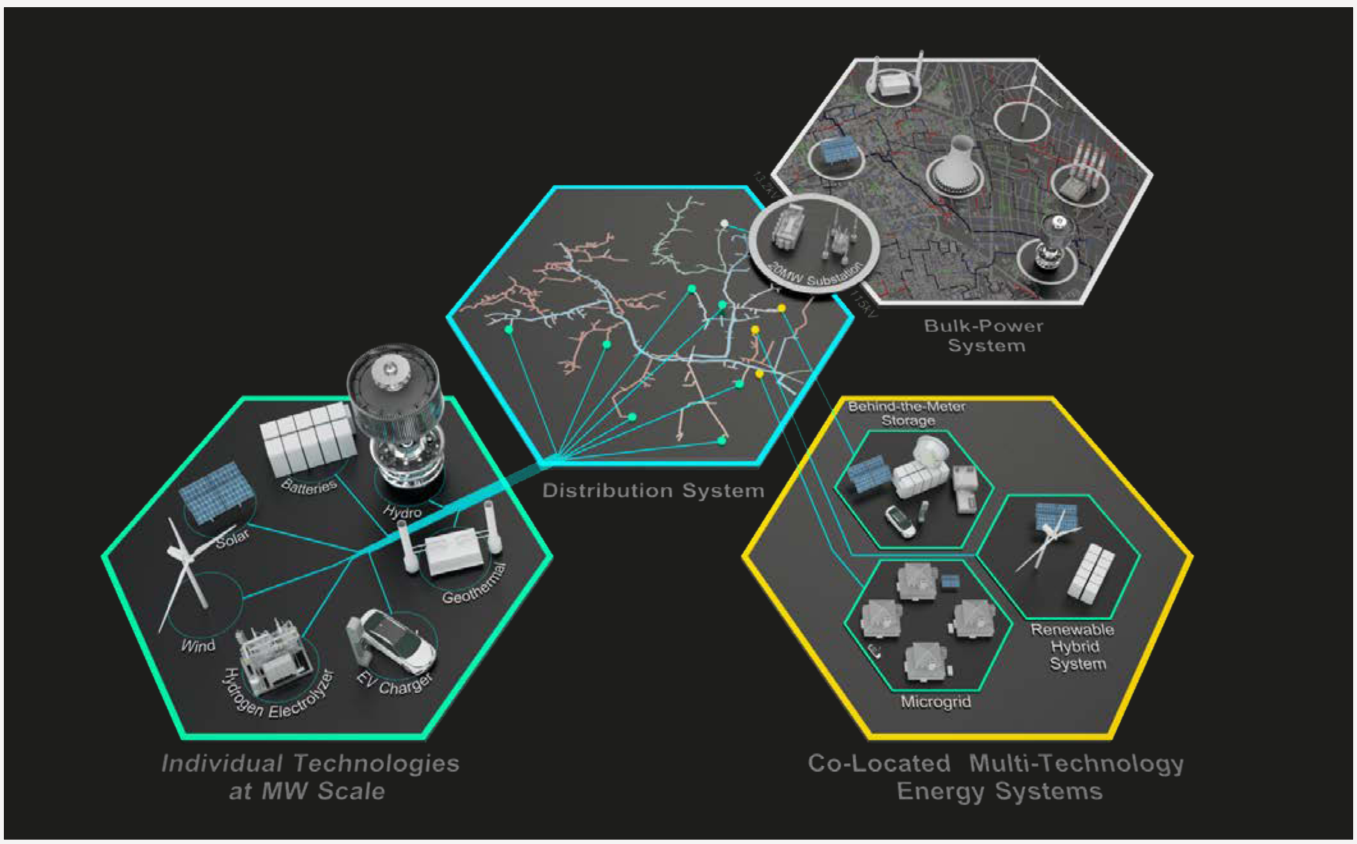
Improving Integration and Expanding Market Adoption of Distributed Wind Technology Through Outreach

The project team for the Microgrids, Infrastructure, Resilience, and Advanced Controls Launchpad (MIRACL) conducted outreach through the production and distribution of an Office of Energy Efficiency and Renewable Energy (EERE) fact sheet across digital and print channels to attract future project partners from the electric utility, wind, microgrid, and distributed energy resource industries.

Significance and impact:

MIRACL seeks to equip and validate wind technology as a plug-and-play resource that can work with solar, storage, and other DERs in hybrid systems. MIRACL outreach activities are the first step toward attracting relevant industries to join this project, helping advance the current state of the art and fostering wider adoption of distributed wind energy technologies.



Integrating wind with diverse technologies creates a larger system that provides a range of benefits, including improved resiliency and flexibility.
Graphic created by Josh Bauer, NREL

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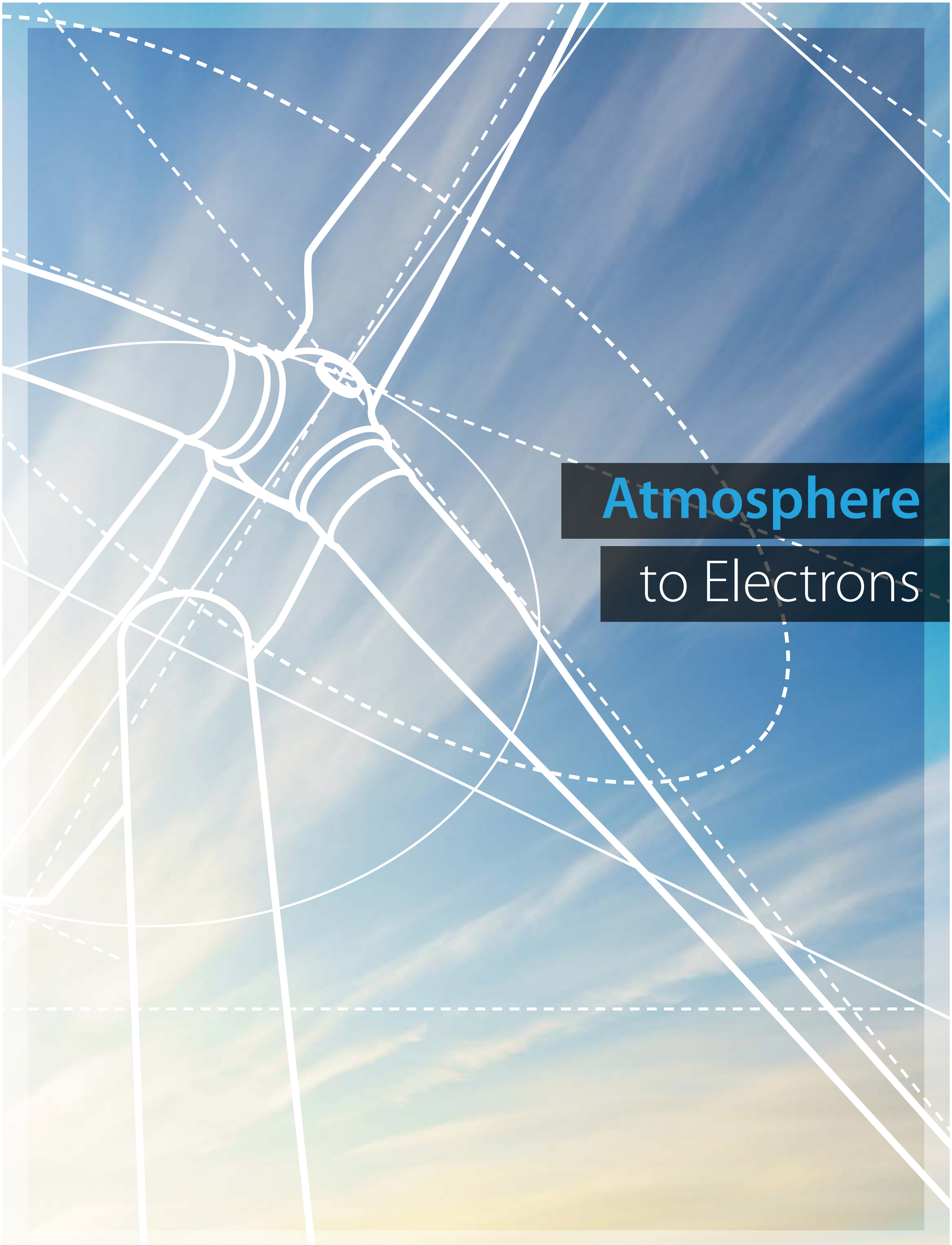
Turbines at the Ready: Multilaboratory Effort Creates Assessment for Deployable Turbines in Defense and Disaster Relief Applications

The Defense and Disaster Deployable Turbine project is a multilaboratory effort that includes Sandia National Laboratories, Idaho National Laboratory, and NREL. Its purpose is to create a market assessment for deployable turbines in defense and disaster-relief applications. The NREL team focused on an assessment of the disaster-relief market and a review of deployable wind turbine technology constraints. Sandia National Laboratories published a technical report on the team's research efforts and findings.

Significance and impact:

This report identifies the market opportunities for deployable wind systems for defense and disaster-relief applications, which sets the stage for developing and publishing the minimum requirements for systems to meet those opportunities and defining and publishing the technology development needs associated with those opportunities. When completed, this work will help determine whether there is a viable market for defense and disaster deployable turbines, and if so, how to best meet the needs of that market. This work is part of a larger effort to help the U.S. Department of Defense identify and deploy renewable energy technologies to reduce fuel consumed in meeting operational energy needs.

Atmosphere to Electrons



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Forecasters Get Wind of Mountain Impacts on Performance of Wind Turbines and Power Plants

Large mountains can modify weather downstream of terrain, thereby creating mountain waves that can impact the output of wind turbines and wind power plants in the path of these waves. Several such cases of mountain waves occurred during the Second Wind Forecast Improvement Project (WFIP2) in the Columbia Basin in the Pacific Northwest of the United States. Collaborative research between NREL, the University of Colorado, the National Oceanic and Atmospheric Administration, Pacific Northwest National Laboratory, and industry researchers demonstrated that mountain waves not only occur frequently in areas of complex terrain, but they can be emulated with mesoscale models. These waves can impact wind turbine and wind power plant output; therefore, they should be considered when designing, building, and forecasting for wind power plants in areas of complex terrain.

Significance and impact:

By demonstrating the impacts complex terrain can have on the performance of wind turbines and wind power plants, researchers conclude that forecasters should be informed when mountain waves occur and receive information about wind variability so they can act accordingly (e.g., when setting day-ahead positions for balancing reserves and schedules). Information about the occurrence of mountain waves adds value by communicating the risk and probability of variability in power output, which helps when planning for possible extreme situations.

The WFIP2 project field campaign in the Columbia Basin resulted in observing phenomena that impact wind conditions at turbine height in mountainous terrain. *Photo of Columbia Basin courtesy of Shutterstock*

Mesoscale-Microscale Coupling Model Development and Validation

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Cutting Through the Gray: Researchers Evaluate Procedures To Model Turbulence in High-Resolution Mesoscale Simulations

Developing high-resolution, regional-scale (mesoscale) turbulence models is a challenge for wind energy researchers. These weather models are typically run with higher-magnitude resolutions than turbulence-resolving wind-plant-scale (microscale) models can handle alone. Wind energy researchers now couple these two models, which have benefits for subkilometer resolution in the mesoscale model, but coupling can also complicate the task of turbulence modeling and lead to inaccurate outcomes. This is especially the case at horizontal resolutions between meso and microscales, known as the "gray zone," an area in which most mesoscale turbulence parameterizations perform poorly. Wind researchers at NREL and the National Center for Atmospheric Research published "Simulating Real Atmospheric Boundary Layers at Gray Zone Resolutions: How Do Currently Available Turbulence Parameterizations Perform?" in the open-access journal, ***Atmosphere***, which sets forth a procedure other researchers can use to evaluate new or improved solutions to resolve gray zone issues.

Significance and impact:

There is an urgent need for a robust gray-zone modeling solution to ensure that research and technology decisions are based on reliable results. Researchers indicate that this modeling solution could take shape in a variety of ways, but that it should be evaluated against existing alternatives following the procedure they set forth. By laying this groundwork, this research advances the field toward developing a validated way to improve high-resolution mesoscale models that ultimately improve renewable energy output, including wind, with improved characterization, prediction, and understanding of atmospheric science under a wide range of realistic operating conditions.

High-Fidelity Modeling

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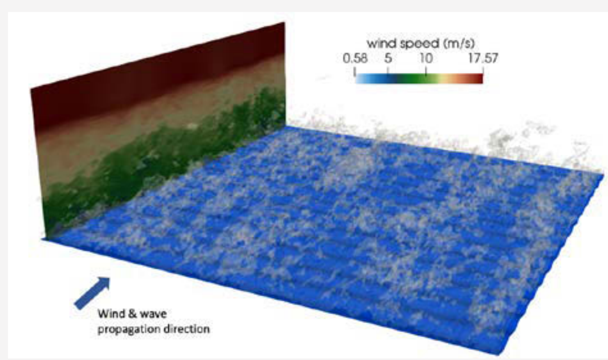
New ExaWind Capability Enables Simulation of the Marine Atmospheric Boundary Layer

NREL's High-Fidelity Modeling team implemented a new moving-wave boundary condition in the ExaWind modeling and simulation environment for offshore atmospheric dynamics. This is a key first step in preparing for high-fidelity simulations of offshore floating wind turbines and wind farms.



Simulation of wind over waves using ExaWind's Nalu-Wind flow solver. This snapshot highlights how water waves can enhance wind turbulence, which is important in designing floating offshore turbines. *Graphic by NREL*

Significance and impact:

Offshore environments are characterized by complex interactions at the air-sea interface, such as large nonlinear wave propagation and wave breaking, which enhance the exchange of energy and momentum between the oceans and the atmospheric boundary layer above it. These interactions also play a key role in the hydrodynamic and aerodynamic loading of floating offshore wind turbines. The implementation of a new moving-wave boundary condition helps researchers obtain a deeper understanding of the coupling between wind and ocean waves, which contributes to improvements in offshore wind turbine design.

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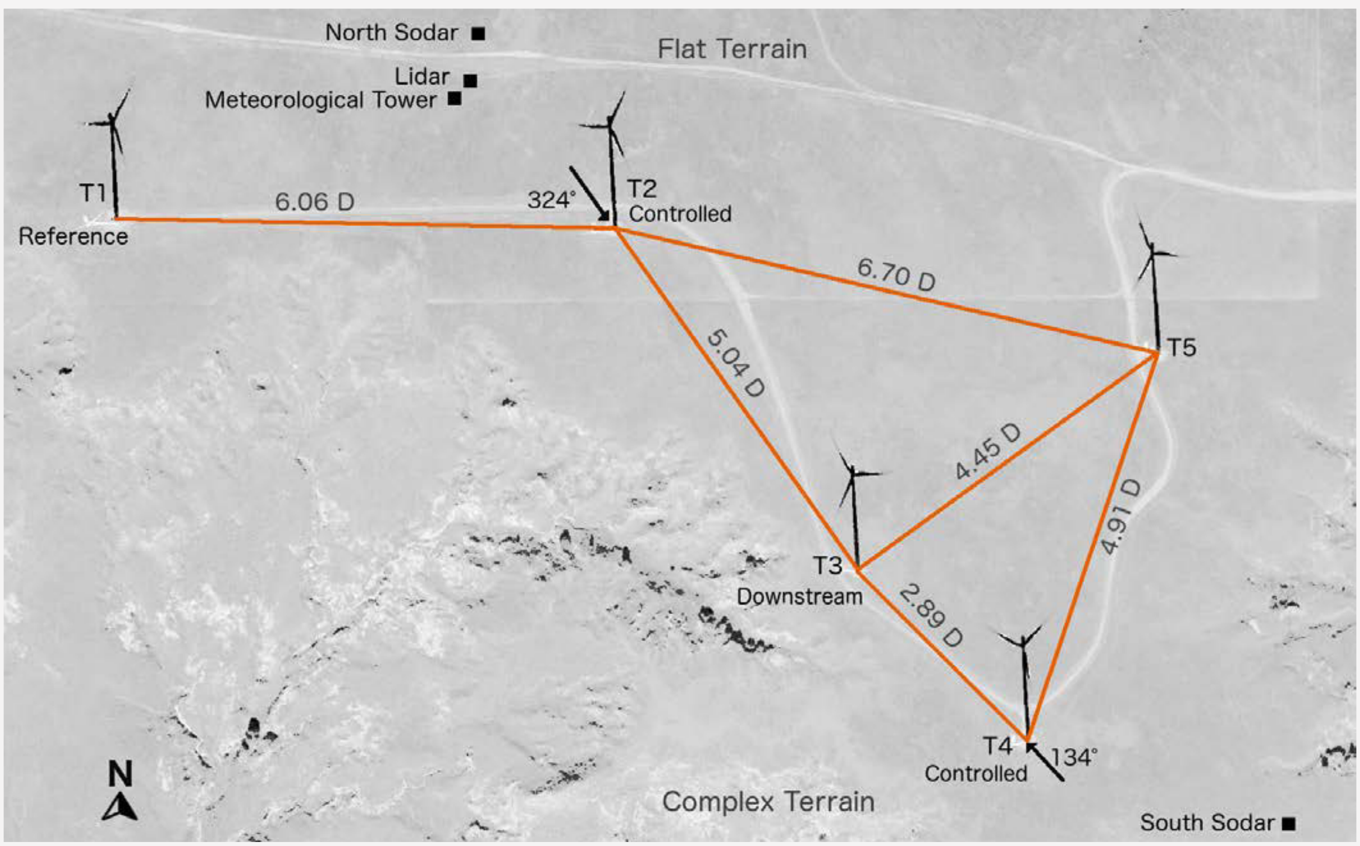
Completion of 2-Year Wake Steering Field Campaign Helps Validate Atmospheric Flow Models

Performed in partnership with NextEra, NREL completed a 2-year field experiment using a cluster of five wind turbines at an operational, utility-scale wind plant in northern Colorado. By deploying extensive instrumentation to measure flow conditions ahead of and behind the wind turbines, the study enabled researchers to measure and control wind turbine operation and evaluate the performance and structural response of the wind turbine system under different environmental conditions and operational strategies.

Significance and impact:

This is the first public, long-term wake-steering experiment conducted at an operational, utility-scale wind power plant. Rich in atmospheric and turbine measurements, the observational data set resulting from this campaign helps quantify the effect of wake steering as a control strategy on the performance and reliability of individual, utility-scale wind turbines. In addition, the dataset collected will be used to validate a wide range of NREL flow models (from FLOw Redirection and Induction in Steady State [FLORIS] to FAST.Farm to ExaWind) and will be shared with the international community for validation of other codes, which helps ensure the accuracy of these computer models to reduce the levelized cost of wind energy.



NREL measured the impact of steering individual turbine wakes away from downstream turbines at NextEra Energy Resource's Peetz Table Wind Energy Center.
Figure by Katherine Fleming, NREL

Aeroacoustic Assessment Wind Plant Control

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Changes in Wind Turbine Noise with Yawed Operation Could Improve Siting Decisions

Aeroacoustic noise, the noise generated by a turbine as its blades cut through the air, depends on boundary layer properties along the length of the blade and the speed at which the rotor spins the blades. Using the OpenFAST aeroacoustics module, researchers find that changes in turbine noise output can arise through yawed operation, which reduces rotor speed for high yaw offset angles.

Significance and impact:

Given public concerns about wind turbine noise and the need for observational data required for regulators to establish noise restrictions, modeling aeroacoustics noise with OpenFAST helps show how active control strategies such as yawing turbines could lead to practical noise reduction methods and technology for more widespread commercial deployment of wind turbines.

Advanced Flow Control Science

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NREL Boosts Speed and Accuracy of Wind Plant Optimization Model

NREL released a new version of its FLORIS model for wind plant performance optimization. The latest update combines the new three-dimensional physics of the curl wake-steering model with the analytical Gaussian model's speed to enhance FLORIS' ability to accurately design and analyze wind power plant control strategies for larger arrays of turbines.

Significance and impact:

Wake steering provides wind plants with important increases in power production for utility-scale wind farms. The new gauss-curl hybrid model predicts the impact of a set of counter-rotating vortices on wake control, resulting in much greater potential to improve wake steering when turbines coordinate based on these vortices, which can help wind energy facilities to improve productivity and increase profits.

Jennifer King and her colleagues advance control strategies to improve the performance of wind power plants. *Photo by Dennis Schroeder, NREL 58254*

NREL Research Establishes Best Practices for Atmospheric Surveying for Wake Modeling

NREL researchers upgraded FLORIS to allow for inflow wind modeling to be spatially heterogenous in wind speed, wind direction, and turbulence. Details of this work are included in a journal article, "Design and Analysis of a Spatially Centered Wake," published in *Wind Energy Science*.

Significance and impact:

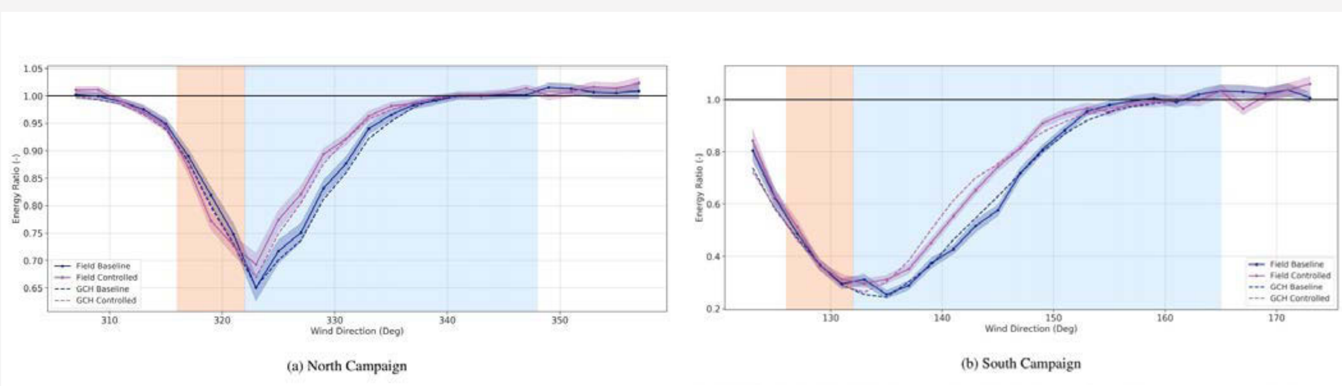
Modeling the power production of large wind farms accurately and completely is challenging because of the differing size and terrain of wind farms, along with changing weather patterns. Instead of using render inflow modeling based on homogenous inflow patterns, NREL researchers made critical improvements to FLORIS that allow for far more accurate, realistic modeling for large wind farms. They also validated these improvements to establish best practices for atmospheric surveying for wake modeling.

Results from Field Campaign Close Match of Latest FLORIS Model

FLORIS researchers submitted a second journal article centered on using FLORIS to model wake steering, NREL researchers documented a complete field campaign at a commercial wind site comparing the results with the latest FLORIS model, showing close alignment between field and model results.

Significance and impact:

In addition to allowing researchers to validate the gains in energy production predicted by the FLORIS tool with actual field results, data show an overall reduction in wake losses of approximately 6.6% for the regions of operation, which corresponds to achieving roughly half of the static optimal result.



These figures show the change in energy ratio (a metric of reduced energy production because of wake losses) from baseline operation (blue) to under wake-steering operation (magenta). Field results are shown in the solid line, whereas FLORIS predictions are shown in the dashed line, indicating good general agreement with the gain in energy production FLORIS predicts. *Graphic by Paul Fleming, NREL*

Wind Direction Variability Improves Energy Production When Turbine Separation Distance Increases

Published in *Wind Energy Science*, NREL authors of the article "Design and Analysis of a Wake Steering Controller with Wind Direction Variability," discuss a new method for designing wind farm controllers assuming realistic uncertainty of critical wind measurements.

Significance and impact:

By accounting for wind direction variability, researchers found that energy production improved as the separation distance between turbines increased, whereas relative improvement remained roughly the same for the range of turbulence intensity values considered. These methods enable the successful design of wake-steering controllers, even assuming the presence of uncertainty in critical measurements.

Systems Engineering Optimization

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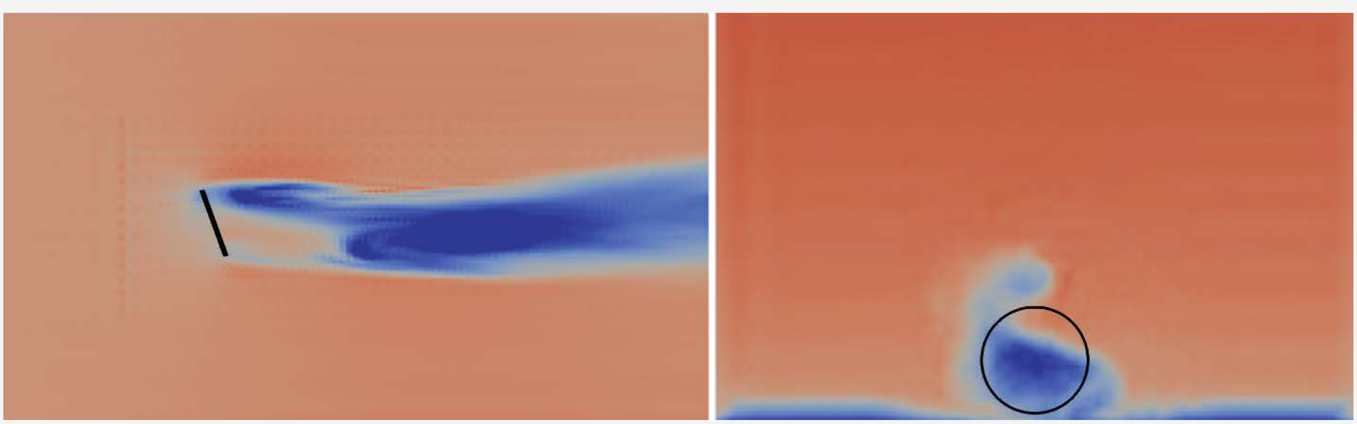
New Unsteady Solver Unlocks Possibilities for Plant Controllability Studies

A new unsteady solver has been created for the systems engineering model, WindSE, which allows it to resolve wind turbine blades (as "actuator lines") and wakes more accurately. Because WindSE provides adjoints, essentially sensitivities between user outputs and simulation parameters, there is now a direct connection between turbine blade lift and drag profiles and plant-level power production.

Significance and impact:

The new addition to WindSE unveils a new class of simulation, optimization, and sensitivity analysis studies that link wind-turbine-focused design to plant-level flow characteristics and power production. As a next step, this contribution empowers NREL to conduct blade design optimization to improve wake deflection when doing wake steering. Future work will focus on turbine-plant co-design, wherein the design geometry and the control strategy are developed in concert with one another to maximize performance in complex scenarios.



Top-down (left) and downwind (right) facing slices of turbine wake show unsteady actuator line method in WindSE. *Graphic by Ethan Young, NREL*

Offshore Wind Research & Development

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FAST.Farm Targets Future Improvements To Advance Wind Farm Development

NREL completed a study to validate the structural response predicted by FAST.Farm against high-fidelity-coupled Simulator fOr Wind Farm Applications (SOWFA)-OpenFAST results for a series of small wind farm scenarios with structurally flexible wind turbines. Higher differences were observed for downstream turbines with low ambient turbulence intensity inflow or yawed turbines, suggesting areas where the wake dynamics modeling of FAST.Farm could be improved.

Significance and impact:

New validation results establish confidence for applying FAST.Farm to wind farm power performance and loads analyses, and for identifying areas in which further model validations and model improvements should be targeted. A draft paper summarizing the development of FAST.Farm and validation results was submitted to the journal ***Wind Energy***.

OC6 Phase I Dives Deep To Improve Offshore Wind Design Tools

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Phase I of the OC6 project examines why offshore wind design tools underpredict the hydrodynamic loading and response of semisubmersibles at their surge-and-pitch natural frequencies. To examine this issue, the OC6 group validated a variety of tools against two data sets, focused on breaking apart the hydrodynamic load components. Results show that the modeling approaches underpredicted all load components and attempts to tune models for one condition worsened results for other conditions, which indicates that some physics are missing in the current modeling approach. Further work with higher-fidelity tools is ongoing to understand what physical elements are missing.

Significance and impact:

The OC6 project has identified the largest sources for underprediction in hydrodynamic loading and response—an important first step toward more accurate modeling tools that help design more optimized, cost-effective offshore wind semisubmersible structures.

The validation campaign of the OC6-DeepC wind floating semisubmersible with rigid tower at the Maritime Research Institute of the Netherlands will help improve designs of semisubmersible turbine platforms.
Photo by Amy Robertson, NREL

East Coast Wind Resource Characterization Gets Boost from Multilab Project

National laboratories including NREL contributed to the development of a Funding Opportunity Announcement (FOA) for offshore wind energy. As part of this collaborative effort, researchers investigated and outlined the research requirements for the FOA, which focuses on two topic areas: improving wind resource modeling and predictions in offshore wind energy development areas, and enabling the demonstration of a novel technology and/or methodology that will advance the state of the art of offshore wind energy in the United States.

Significance and impact:

DOE and the National Oceanic and Atmospheric Administration will aid the FOA winner in addressing primary challenges that the offshore wind industry faces with respect to wind resource characterization, including wind forecasting. By laying the groundwork for this FOA project, NREL helps ensure that field campaign activities directly improve wind resource characterization in the U.S. East Coast offshore environment. With these improvements, researchers can incorporate the new understanding into foundational numerical weather forecasting models and other physics-based atmospheric and oceanographic models to improve wind energy forecasts to advance the offshore wind industry.

Wind characterization efforts on the east coast of the United States helps to ensure more offshore wind plants like the Block Island Wind Farm can be developed.
Photo by Gary Norton, NREL 41993

Advanced Components, Reliability & Manufacturing

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Bolt of Inspiration Charges Improvements for Lightning Protection System

To help protect thermally welded blades from lightning strikes, NREL researchers designed a 5-m blade tip section and determined the optimum joining methodology to accelerate learning (to "mock weld" the blade) to design a lightning protection system that will be infused into the blade skin. Plans are also underway for additional 1-mr, 2-panel evaluations to accelerate learning in the National Technical Systems Pittsburgh Lightning Test Center during the 5-m blade tip strike trial.

Significance and impact:

Having designed the lightning protection system component and created the mock welding method with materials at NREL's Flatirons Campus, the lab can move toward manufacturing the blade tip section. Once manufactured, researchers can validate the new section at National Technical Systems, with the ultimate goal of protecting turbines from lighting strikes in the field.

NREL researchers plan to validate the design of their wind turbine blade tip lightning protection system to see how it holds up during lightning strikes.
Photo by Dave Snowberg, NREL 51773

3D Printed Core Structures for Wind Turbine Blades

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NREL Has Entered the Chat: Establishing Online Collaborative Tools To Advance Large-Scale 3D Printing Applications

A joint collaboration meeting was held at Oak Ridge National Laboratory's (ORNL's) Manufacturing Demonstration Facility to launch the 3D Printed Blade Core Material project between NREL and ORNL. NREL is supporting the design, structural analysis, blade manufacture, and blade evaluation objectives while ORNL is supporting the additive materials evaluation and characterization, design for additive manufacture, and large-scale 3D printing objectives. Contributions from both labs help will help to engineer lightweight, high stiffness-to-mass ratio, blade core structures.

Significance and impact:

The meeting established the online collaborative tools required to share data between the labs to advance large-scale 3D printing applications in the wind industry from blade manufacturing tooling into direct manufacture of large-scale blade structural components. These data sharing efforts will help NREL and ORNL explore how emerging 3D printing technologies can manufacture novel blade core structures to dramatically increases strength and stiffness of turbine blades with little impact to blade mass, helping to further reduce the levelized cost of wind energy and simplifying blade manufacturing processes.

MADE3D (Manufacturing and Additive Design of an Electric Machine Enabled by 3D Printing)

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Nonprovisional Patent Submitted To Advance Large-Scale Direct-Drive Generators

A U.S. nonprovisional patent application, "Additive Design and Manufacturing for Electric Machines," corresponding to NREL record of invention Nos. 18-64 and 19-60, was filed at the United States Patent & Trademark Office and received Application No. 16/718,630.

Significance and impact:

Direct-drive wind turbine generators operate in a low-speed, high-torque regime; therefore, the size, weight, and cost of such units can be prohibitive, especially for power ratings over 10 MW. Using additive manufacturing and topology optimization routines can reduce direct-drive generator size and weight, which helps to decrease capital costs, operations and maintenance costs, and improving direct drive performance. This method is applicable to other industries in which size and weight of the powertrain are critical, such as electric aircraft.

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Simulator Helps Shine Light on Axial Cracking Failure Mode, Improving Turbine Reliability

NREL researchers published, "Validation of Combined Analytical Methods to Predict Slip in Cylindrical Roller Bearings," in the journal, *Tribology International*, on analytical modeling and validation of cage and roller slip in cylindrical roller bearings. A software record was created for the analytical model, which was validated with measurements acquired in a General Electric 1.5 SLE wind turbine at NREL's Flatirons Campus in a cooperative research and development agreement project with bearing manufacturer, SKF, and gearbox manufacturer, Winergy.

Significance and impact:

An analytical model is valuable for the industry to evaluate the effectiveness of bearing design and lubricant property changes in reducing bearing slip, which may be a root cause of bearing axial cracking or other bearing failures caused by skidding. The analytical model is being considered by SKF for a software evaluation license and could help resolve premature intermediate and high-speed bearing failures caused by axial cracking—one of the predominant failure modes in wind turbine gearboxes.

Resolving issues like bearing axial cracking helps to reduce operation and maintenance costs associated with replacing wind turbine parts. *Photo by Dennis Schroeder, NREL 49408*

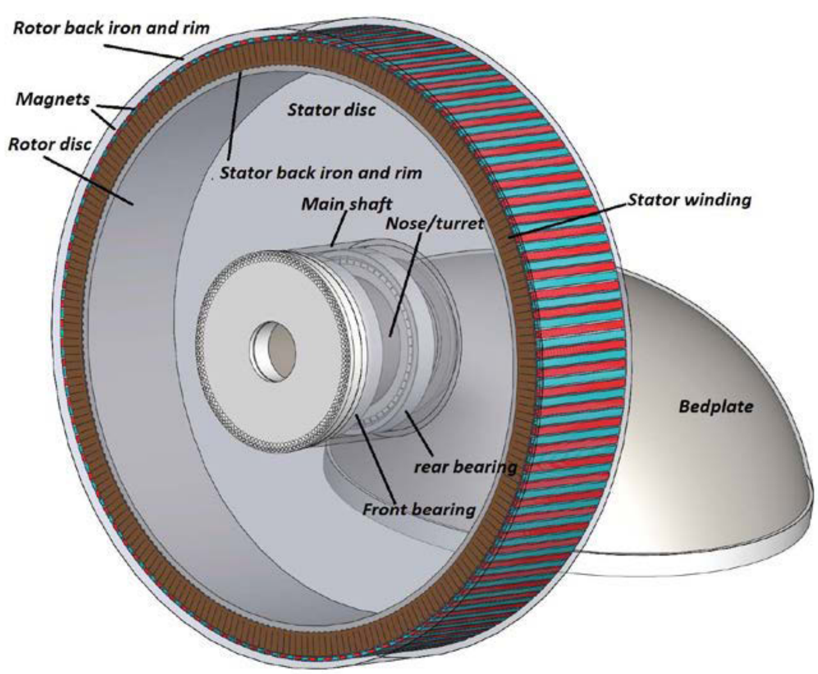
Point of contact: Jonathan Keller, Jonathan.Keller@nrel.gov WETO.1.5.91.401 I WETO.1.5.91.402

Baseline 15-MW Direct-Drive Generator Design Could Reduce Cost of Offshore Wind Energy

NREL researchers published a technical report, "Definition of the IEA Wind 15-Megawatt Offshore Reference Wind Turbine," in collaboration with the Technical University of Denmark and University of Maine, through the International Energy Agency. A portion of this report describes the development of a 15-MW conceptual direct-drive permanent-magnet generator design for comparison with the GE Global Research low-temperature superconducting generator, American Superconductor Corporation high-temperature superconducting generator, and WEG Energy Corporation high-efficiency generator.

Significance and impact:

The baseline direct-drive permanent-magnet generator conceptual design provides a common comparison point for different generator technologies and LCOE estimation relevant for large, offshore wind power plants. Among many projects, the conceptual design will be used for the Advanced Lightweight Generator FOA 1981 projects and the Annual-Operating-Plan-funded Manufacturing and Additive Design Enabled by 3D Printing (MADE3D) project. The baseline generator is 372 metric tons in weight, rated for 21 meganewton meters of torque, over 10 m in diameter and 2.2 m in length, and 96.55% efficient. Ultimately, NREL will work with each company to develop a conceptual direct-drive permanent-magnet generator design that can reduce the cost of offshore wind.



CAD model of the 15-MW direct-drive wind turbine generator. *Graphic by NREL*

Standards Support and International Engagement

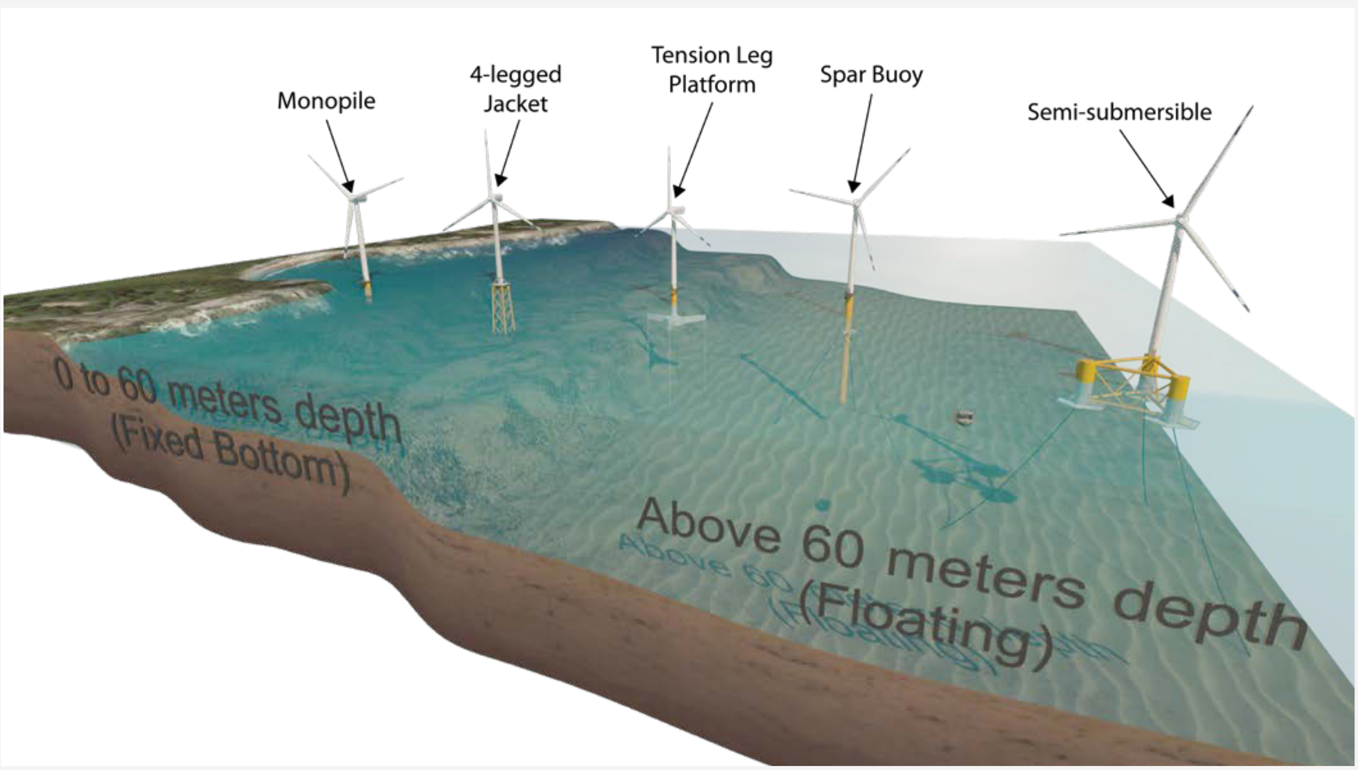
Point of contact: Jeroen van Dam, Jeroen.van.Dam@nrel.gov WETO 1.6.1.401

U.S. Wind Energy Standards Summit Explores Standards for Offshore Wind Deployment

NREL collaborated with the American Renewable Energy Standards and Certification Association to organize the annual U.S. Wind Energy Standards Summit in San Diego. Approximately 40 industry stakeholders (including representatives from original equipment manufacturers, owner/operators, insurance companies, consultants, universities, national laboratories, and government organizations) participated in the event, which aims to engage and educate industry on the development of international and domestic wind energy standards.

Significance and impact:

To be effective, a requirement written into a standard needs industry participation to properly address stakeholders' needs. In return, industry must fully understand the requirements in the standards and its intentions to ensure uniform implementation. For the United States, one of the current key items is offshore wind and the design requirements needed to ensure safe and reliable operation. By helping organize the U.S. Wind Energy Standards Summit, NREL informed future design requirements needed to address U.S.-specific issues. This year, offshore wind was a high priority of the summit, including issues such as hurricanes, or floating systems related to water depth—all things that need standards for wider offshore wind deployment.



Above a water depth of 60 m, floating offshore wind turbine platforms become more common than their fixed-bottom cousins, but they face challenges. NREL helped organize the U.S. Wind Energy Standard Summit to address U.S.-specific offshore wind issues, such as hurricanes. *Illustration by Josh Bauer, NREL*

Grid Integration

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Wind Plant Controller Architecture May Lower Levelized Cost of Energy

NREL researchers created a platform for integrated wind plant control that includes operational modes for minimizing wake losses as well as wind plant operation based on maximizing value streams for grid services. This allows for an understanding of how various forms of grid services from wind generation, with uncertainties around their availability and output levels, can be quantified during a particular time frame, such as a day or an hour ahead. Using the CGI at the Flatirons Campus in conjunction with the GE 1.5-MW turbine, researchers will validate the plant controller's ability to provide various grid services and operational control during the plant's transition from one service mode to another.

Significance and impact:

This platform lays the foundation for developing a wind plant controller that values wind power plant operational and grid value streams and minimizes operation and maintenance costs. The controller will be demonstrated at NREL's Flatirons Campus grid facility and the resulting data will be provided to industry. This controller will increase the energy output of wind power plants and enable them to provide grid services, such as up-and-down regulation, to energy markets and system operators, thereby increasing the value of the power output and leading to a lower LCOE.

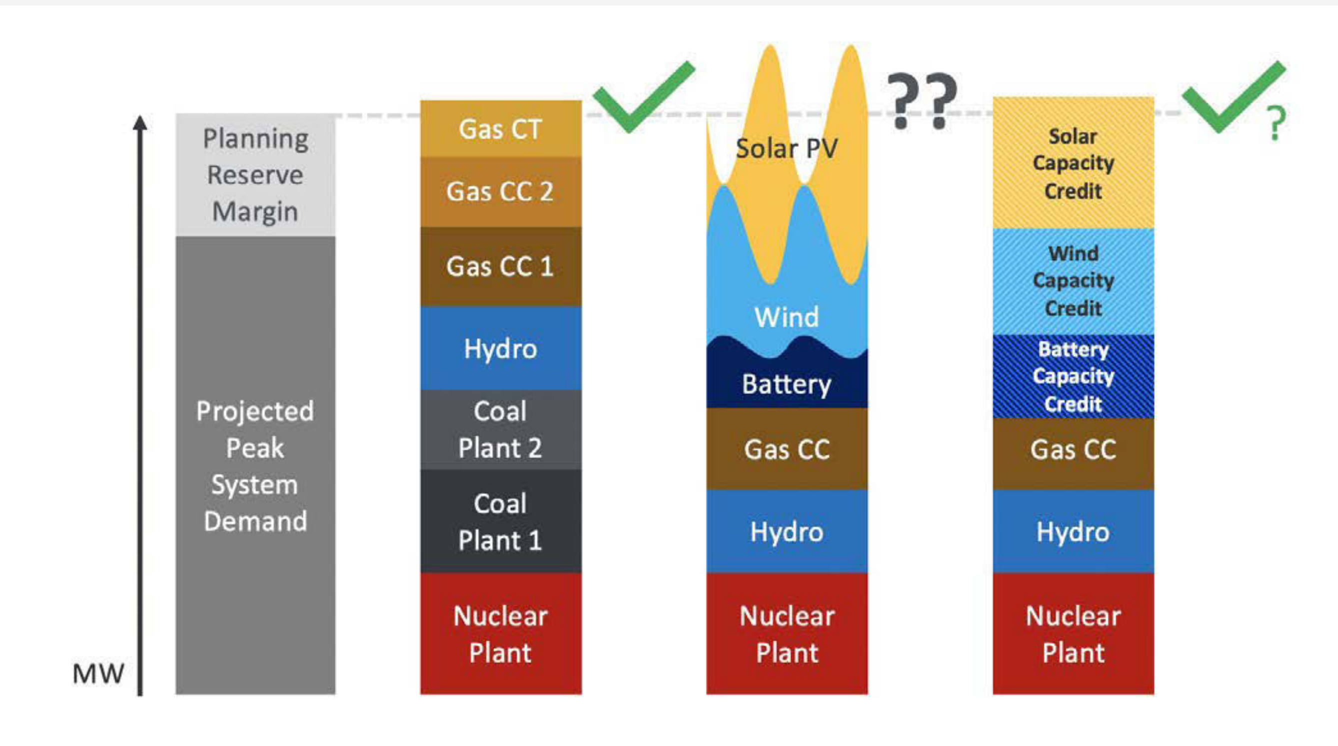
As the share of renewable energy on the grid continues to increase, the need for real-time plant controls to adjust to energy variability will grow, and these controls can help ensure renewables provide enhanced system reliability and grid services. *Photo by Dennis Schroeder, NREL 55200*

NREL's Probabilistic Resource Adequacy Suite Unveiled at NERC

NREL researchers presented their Probabilistic Resource Adequacy Suite at a North American Electric Reliability Corporation (NERC) forum that highlighted key aspects of the lab's groundbreaking work in adapting and developing new probabilistic methods and tools in anticipation of the needs of a future with higher penetrations of variable and energy-limited resources like wind power.

Significance and impact:

The Probabilistic Resource Adequacy Suite is NREL's collection of tools for studying unserved energy risk in electric power systems across space and time. This work draws on NREL's activity in probabilistic assessment, which has been conducted for many key long-term studies that characterize future power systems. It allows NREL to assist NERC in accessing future sources of resource adequacy risk for systems with high amounts of wind power. This capability makes it possible to evaluate the reliability of future wind scenarios, thereby realizing a resilient, reliable future power grid.



Expansion models and planning reserve margins, like those shown here, enable a better understanding of grid reliability. In this work, NREL researchers used probabilistic assessment to characterize future power systems to evaluate the reliability of future wind scenarios on a power grid. *Graphic by NREL*

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NREL and General Electric Analyze Electrical Oscillations in Wind Power Plants

In the article, "Impedance Analysis and PHIL Demonstration of Reactive Power Oscillations in a Wind Power Plant Using a 4-MW Wind Turbine," submitted to ***Frontiers in Energy Research***, NREL researchers discuss experiments performed in partnership with General Electric on a 4-MW wind turbine drivetrain to analyze reactive power oscillations in wind power plants, similar to those experienced in an offshore wind power plant in the United Kingdom during a major blackout event in August 2019.

Significance and impact:

The power-domain impedance theory developed for the analysis of active and reactive power oscillations during this work proved to be an effective tool for the analysis and mitigation of low-frequency oscillations in wind power plants. Such characterization can avoid oscillation events in wind power plants and prevent the loss of bulk generation from wind during grid events, thereby increasing grid flexibility to achieve higher penetration levels for wind energy.

NREL Creates First-Ever Impedance Measurement System of Wind Turbines using a Multimegawatt Grid Simulator

An NREL team has developed an impedance measurement system, which can characterize the electrical behavior of multimegawatt wind turbines and inverters at different frequencies. The developed system leverages a 7-MW grid simulator and GPS-synchronized medium-voltage data acquisition system at the Flatirons Campus to enable advanced testing of wind turbines and inverters. Impedance measurement and impedance-based stability analysis have received much attention over the past 4—5 years by the wind and solar photovoltaic (PV) industry to understand the stability implications of wind and solar PV power plants.

Significance and impact:

The impedance measurement system developed at NREL is the first of its kind across the globe to provide comprehensive impedance measurements of wind turbines and inverters at the multimegawatt scale. Measurement impedance responses of wind turbines can help evaluate different dynamic stability problems, serve as a platform for high-fidelity model validation for conducting comprehensive grid integration studies, and support the development of new technologies, such as grid-forming wind turbines.

Wind Power as Virtual Synchronous Generation (WindVSG)

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Explorations into Interarea Oscillation Damping Help Empower a More Stable Power Grid

NREL researchers have a forthcoming publication on the ability of grid-forming resources to provide interarea oscillation damping. This research includes a theoretical analysis of Type 3 wind turbines in grid-forming mode and Power Systems and Computer-Aided Design modeling of grid-forming/black-start capabilities of Type 4 wind turbines for wide-scale grid studies. This work is being performed in partnership with General Electric.

Significance and impact:

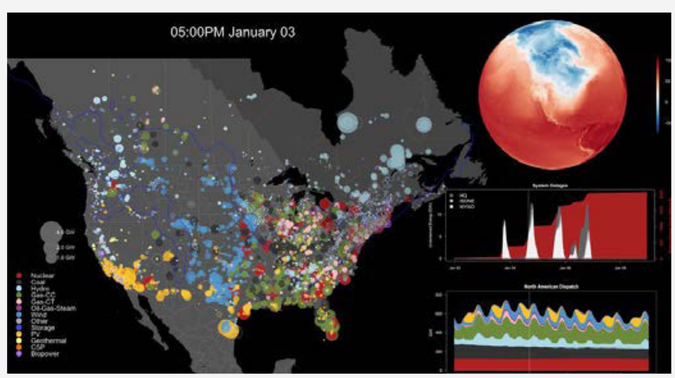
Synchronous generators have served as the only grid-forming resource in the power system. They form the grid by acting as a voltage source and ensuring that voltage magnitude and frequency stay within tolerable limits at every node in the power system. The inverter-based resources (e.g., wind, PV, and battery storage) traditionally operate in the grid-following mode by acting as current sources injecting power into different nodes throughout the power system. As the penetration of inverter-based resources increases, it is necessary for wind and PV to operate as grid-forming sources for stable operation of the power system. Development of control methods for operating a doubly-fed induction generator based on Type 3 wind turbines is an important research task, because Type 3 wind turbines account for 50% of the land-based wind generation fleet worldwide, a trend that will continue for land-based wind power.

North American Energy Resiliency Model (NAERM)

Point of contact: Jessica Lau, Jessica.Lau@nrel.gov WETO.3.1.0.422

Modeling Visualization Showcased at House Energy and Water Appropriations Committee

In a presentation at the House Energy and Water Appropriations Committee on the FY21 DOE proposed budget, Office of Electricity Assistant Secretary Bruce Walker used a slide from the North American Energy Resiliency Model polar vortex visualization video and had a brief exchange with Chairwoman Marcy Kaptur, who emphasized the need for such visualizations to communicate complex energy concepts to the American people.



A snapshot of the polar vortex visualization video from the North American Energy Resiliency Model. *Graphic by NREL*

Significance and impact:

The visualization shows a polar vortex use case, which was designed and led by WETO and Jian Fu. With Walker using NREL's graphic to present to the committee, the lab demonstrated cutting-edge visualization work which can provide essential data and information to those making critical decisions about the U.S. energy grid.

Mitigating Market Barriers

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Researchers Explore if Wind Turbines Cause Barotrauma in Bats

NREL researchers are working to minimize wind energy impacts on wildlife, such as the hoary bat, shown here. This study investigated the potential for wind turbines to cause barotrauma—exposure to rapid pressure variation—and found it unlikely. *Photo by Kathleen Smith, Florida Fish and Wildlife Conservation Commission*

The perception that wind turbines cause barotrauma (harmful exposure to rapid pressure variation) in bats persists in the published literature and news media. As a result, NREL researchers investigated the likelihood of this phenomenon to be published in a forthcoming publication by performing a computational fluid dynamics simulation of a wind turbine and analytical calculations of blade-tip vortices to estimate characteristics of the sudden pressure changes bats may experience.

Significance and impact:

Research results indicate that for bats to experience the largest possible magnitude of low or high pressures, they would almost assuredly collide with the blade. This finding, paired with publications documenting the physiological evidence of blunt-force trauma by wind turbines to bats, suggests that that barotrauma is unlikely to be a significant contributor to bat mortality at wind energy facilities.

Conserving Grouse Species and Advancing Wind Deployment

Point of contact: Cris Hein, Cris.Hein@nrel.gov WETO.3.3.0.401

Grouse populations benefit from large, intact, and undisturbed habitats; they are adversely affected by the influence of humans on the natural environment, but there is uncertainty as to the extent and magnitude of the impact caused by wind energy development. In partnership with the American Wind Wildlife Institute and Western Ecosystems Technology, Inc., researchers conducted a meta-analysis of 10 studies of grouse behavior near wind turbines. The team's findings informed a technical report for the National Wind Coordinating Collaborative that will soon be submitted to a journal.

Increasing our nation's wind energy infrastructure in ways that protect and conserve wildlife depends on finding solutions to wind-wildlife challenges that are scientifically sound and statistically valid. A meta-analysis of 10 studies of grouse behavior in habitats near wind turbines indicates negative impacts but is inconclusive regarding the magnitude of those impacts.
Photo by Tom Kerner, United States Fish and Wildlife Service

Significance and impact:

Through their meta-analysis, researchers found that grouse habitat selection, survival, and lek attendance (where courtship behaviors are displayed) were negatively impacted in habitats in close proximity to wind turbines. However, the magnitude of the effect was small and variable across studies. The technical report and additional studies can be used to inform siting decisions that avoid, minimize, or mitigate impacts to grouse and their habitat.

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Collegiate Wind Competition Organizers Transition to Virtual Format and Select 2021 Teams

Collegiate Wind Competition (CWC) organizers, led by NREL, facilitated the competition's move to a virtual format to accommodate health concerns related to a global pandemic. Organizers also selected the university teams that will participate in the 2021 competition, including 10 returning teams and three new teams.

Significance and impact:

The CWC provides an opportunity for college students to link academic coursework with tangible, hands-on, collaborative learning. Through the competition, students gain valuable real-world experience as they prepare to enter the workforce ideally the wind energy workforce. Many CWC alumni who now work in the wind industry attribute much of their success in finding a job in this industry to the experience they gained from the event.

The 2020 competition's virtual format will safeguard the health of team members, judges, organizers, and other participants while providing the opportunity for college students to gain experience with remote learning, presenting, and networking.

The Collegiate Wind Competition provides college students with the real-world experience needed to enter the wind industry workforce. Organizers moved the competition to a virtual format and selected the 13 university teams that will participate in the 2021 CWC. *Photo by Werner Slocum, NREL*

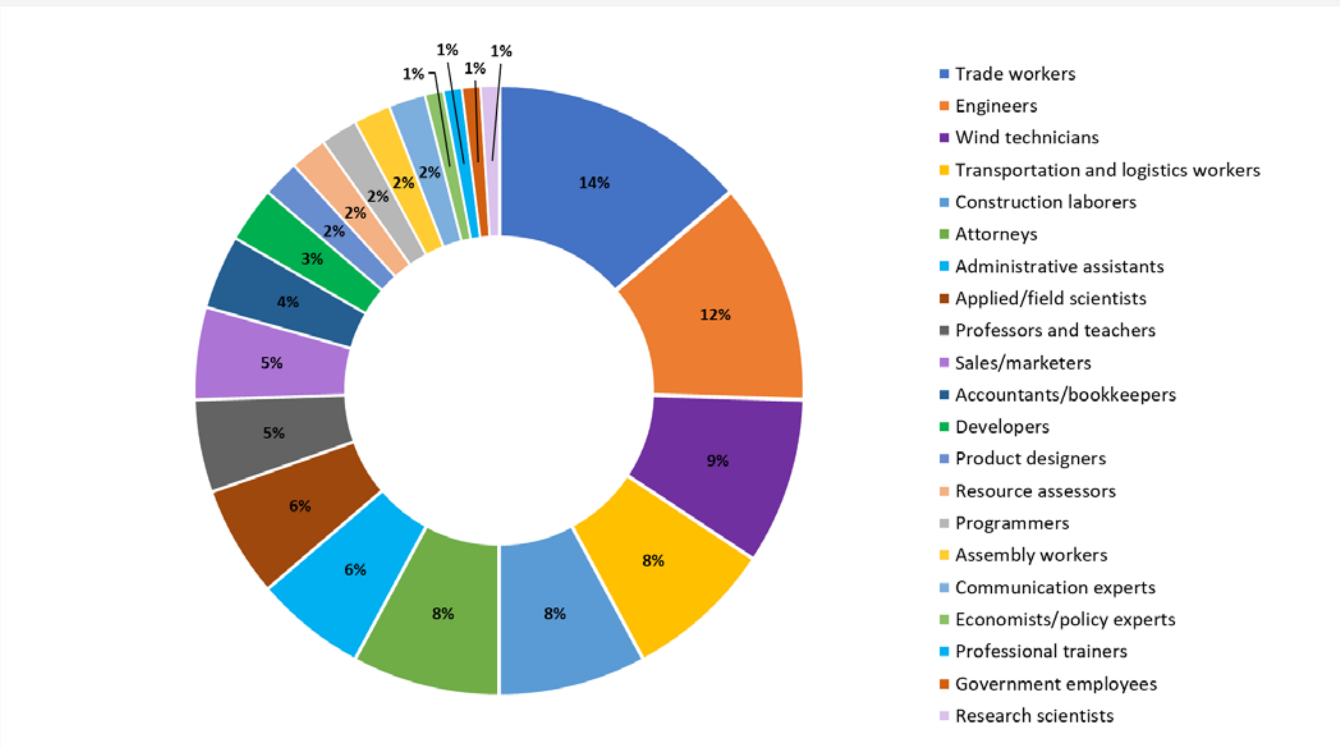
Point of contact: Jeremy Stefek, Jeremy.Stefek@nrel.gov WETO.3.4.0.403

NREL Researchers Survey Wind Industry Employers To Better Understand Wind Workforce Gap

Employment in the wind industry has increased rapidly over the last 5 years, but 68% of wind industry employers reported some or great difficulty finding qualified applicants across most occupations. To better understand employers' difficulty in finding qualified applicants to fill positions across this career sector, NREL researchers designed a survey instrument to gather data on reasons behind their hiring difficulty, desired skills across occupations, and industry awareness of domestic wind education programs from wind industry employers. BW Research is distributing the survey to industry representatives and results are expected summer 2020.

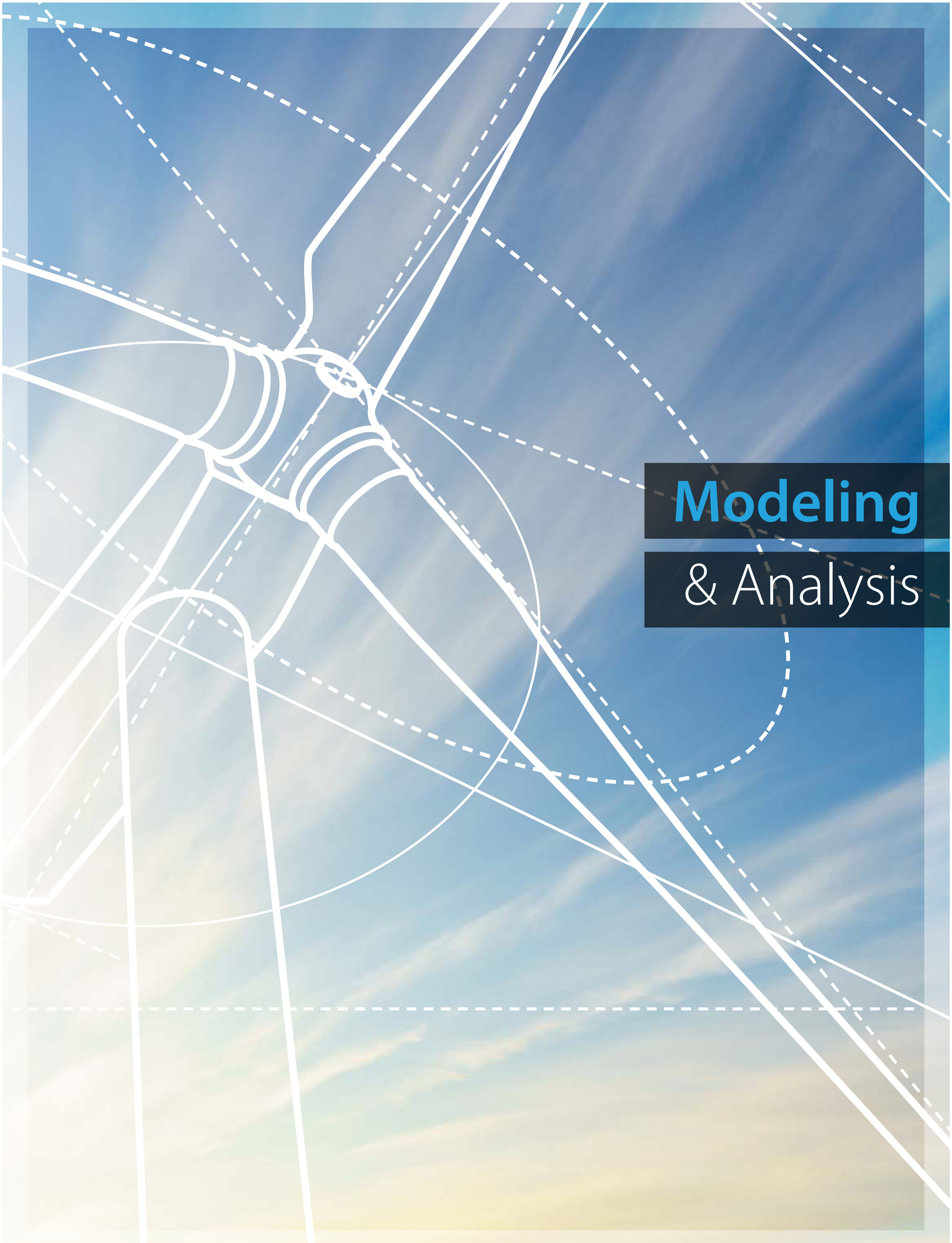
Significance and impact:

This survey of the wind industry will provide valuable data for a follow-on report to the 2019 NREL report, "The Wind Energy Workforce in the United States: Training, Hiring, and Future Needs." This research project aims to understand the primary reasons behind the land-based wind workforce gap and provide detailed reasoning for the gap's existence from industry, educational programs, and the students and recent graduates from these programs. Insights from wind workforce-related research can help refine programs and initiatives aimed at narrowing the gap.



The difficulty of employers identifying well-qualified candidates while wind and renewable energy graduates report difficulty finding jobs in the wind industry suggests a potential gap in the wind industry workforce that the survey may help uncover. *Graphic by Jeremy Stefek, NREL*

Modeling & Analysis



Crowd-Sourcing Success: Researchers Design Open-Source 15-MW Offshore Wind Turbine

NREL led an international team (including the Danish Technical University and University of Maine, with support from General Electric, EDF-R, Senvion, Sintef, Atkins, and Sandia National Laboratories) to develop an open-source conceptual design for a 15-MW offshore reference wind turbine with a fixed-bottom monopile support structure. The design updates the classic NREL 5-MW turbine, which has been extensively used in the wind community but has been outpaced by turbines with larger generating capacities. The IEA Wind 15-MW Reference Turbine includes blade aerodynamic and structural properties; rotor performance characteristics; tower and monopile properties; detailed design of the nacelle, drivetrain, and hub; and a baseline load assessment. The project culminated in an IEA Wind report that summarizes the design results.

Significance and impact:

Researchers, original equipment manufacturers, and project developers can use the IEA Wind 15-MW Reference Turbine to explore new technologies or design methodologies that lower costs, improve performance, and reduce project risk. As these innovative designs are applied to the same reference turbine, their relative impact can be evaluated to identify the most promising pathways for expanded offshore wind deployment. The forward-looking nature of the IEA Wind 15-MW Reference Turbine design allows analysts and policymakers to estimate future costs and deployment scenarios as well as the associated infrastructure needs (e.g., vessels, ports, and manufacturing facilities) to accommodate turbines of this size. Finally, the IEA Wind 15-MW reference turbine provides a valuable educational tool to help wind industry newcomers understand the challenging trade-offs and design optimizations inherent to wind turbines.

An artistic rendering of the IEA Wind 15-MW Reference Turbine. The open-source offshore turbine design allows wind industry contributors to share their designs and innovations with other researchers to accelerate technological development. *Illustration by Josh Bauer, NREL Photo by Werner Slocum, NREL*

Modeling Balance-of-System Costs for Land-Based Wind Plants Can Help Reduce Investment Costs

Point of contact: Annika Eberle, Annika.Eberle@nrel.gov

Balance-of-system (BOS) costs—the costs to perform site preparation, construct foundations and towers, and install electrical infrastructure—currently account for approximately 30% of the capital expenditures needed to install a land-based wind plant. Now, an open-source tool, the Land-based Balance of System Systems Engineering (LandBOSSE) model, is publicly available to help researchers, analysts, wind power developers, government agencies, and other stakeholders quickly estimate BOS costs for land-based wind power plants and explore how various design parameters, labor and equipment rates, and other factors might change these costs.

LandBOSSE helps users explore potential opportunities for reducing a wind project's total investment costs, including labor costs. *Photo by Dennis Schroeder, NREL 53924*

Significance and impact:

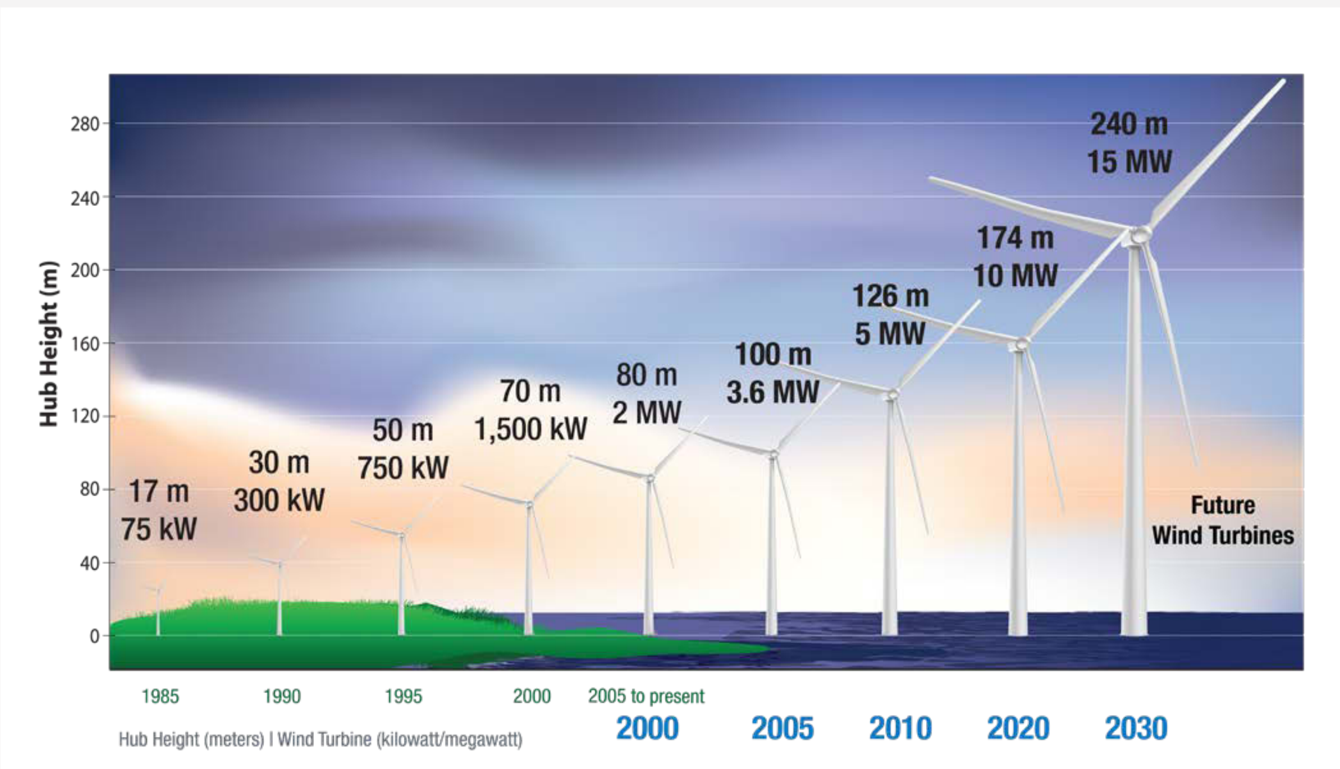
Estimating BOS costs is important because, as the cost of wind turbine hardware decreases, BOS costs account for a larger share of a project's total investment. The ability to quickly estimate BOS costs and iterate around potential design alternatives enables stakeholders to identify the underlying drivers of BOS costs and explore opportunities for lowering this increasing portion of total investment costs.

Floating Possibilities: Introductory Webinar Presents Floating Offshore Wind Technologies

By bolstering the foundational knowledge base of public and key stakeholders, this research supports constructive dialogue around opportunities for floating offshore wind development in deep-water coastal regions of the United States. This research resulted in the development of tailored content to meet both broad-based educational needs and stakeholder engagement objectives around floating offshore wind for WETO.

Significance and impact:

The webinar covered a critical public knowledge gap on floating offshore wind technology, which has rapidly accelerated its commercialization potential in recent years. It was well-attended, tallying 338 live participants and over 2,300 YouTube views of the recorded webinar after promotion across NREL's digital platforms. By publishing the content in a highly accessible video form, the webinar can serve as a valuable educational and public reference resource on floating offshore wind now and for the foreseeable future.



NREL research has helped drive the technology powering increasingly large offshore turbines. For example, a single General Electric 12-MW Haliade-X offshore wind turbine can now power up to 4,500 average U.S. homes. *Illustration by Josh Bauer, NREL*

Energy Sector Modeling and Impacts Analysis

Point of contact: Trieu Mai, Trieu.Mai@nrel.gov WETO.4.1.0.405

Pinpointing Potential: Bringing Offshore Wind onto Tomorrow's U.S. Northeast Grid

NREL researchers have quantified the potential impacts of adding up to 7 gigawatts (GW) of offshore wind on a future electricity system in the U.S. Northeast. The analysis identified potential points of offshore wind interconnection on the New England and New York transmission systems and used hourly wind profiles from the Wind Integration National Dataset Toolkit to assess operational, price, and transmission impacts from injecting offshore wind energy into a 2024 power system representation. The research was completed with input, review, and resources from three NREL centers, ISO New England, and New York ISO. A report was published and has been presented at several stakeholder events, including working group meetings hosted by the Business Network for Offshore Wind Grid & Transmission and the New York State Energy Research and Development Authority.

Significance and impact:

This study is a first-of-its-kind assessment of the potential impact from injecting up to 7 GW of offshore wind energy into the power systems in the U.S. Northeast. It provides power system planners and decision makers with a better understanding of a novel generation source in a position to deliver nearly 8 GW of utility-scale generation in this region by 2030. The study finds that power system operations in the U.S. Northeast can accommodate offshore wind by adapting the system's generation dispatch, with offshore wind curtailment levels of 4%–5%. The number of hours with transmission congestion increases because of the addition of offshore wind, with impacts varying geographically. The 7-GW scenario shows a reduction in locational marginal pricing of 11%, with production cost savings of up to 18%, compared to a scenario with no offshore wind.

PRUF - Wind Plant Performance Benchmarking

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Improving Turbine Performance with Power Curves

NREL researchers, along with external authors, have completed documenting activities of the Power Curve Working Group, including the Share 3 exercise, and published this research in the journal, Wind Energy Science.

Significance and impact:

This article allows industry and research community stakeholders access to well-documented power curve methods for modifying wind turbine performance in light of different atmospheric parameters. Further, it discusses the effectiveness of these power curve methods by evaluating them across 60 real-world power performance evaluations. Finally, this research documents much of the 7-year evolution and findings of the Power Curve Working Group.

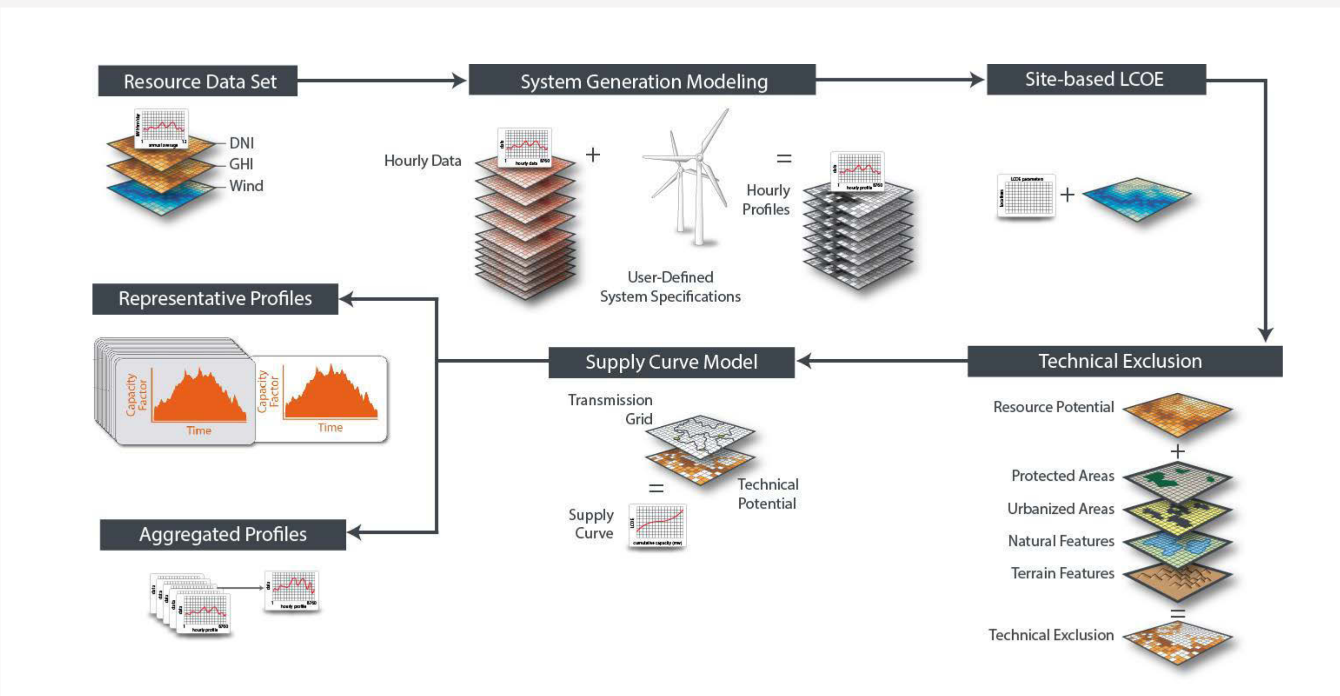
Programmatic Support

Envisioning Renewable Expansion: Open-Source Release of the Renewable Energy Potential Model

The Renewable Energy Potential (reV) model is a platform for the detailed assessment of renewable energy resources and their geospatial intersection with grid infrastructure and land-use characteristics. The model currently supports PV, concentrated solar power, and land-based and offshore wind energy technologies. Modules in the reV framework function at different spatial and temporal resolutions, allowing for the assessment of resource potential, technical potential, and supply curves at varying levels of detail.

Significance and impact:

With this reV model release, industry stakeholders can assess technical potential, spur-line distances and costs, and opportunities for new turbine technologies at both regional and national scales. Multiple external collaborators and industry partners have requested access to the reV model. The open-source release will increase the impact and exposure of this model.



The reV module diagram. The open-source model will help wind industry stakeholders assess the potential and risks involved with land-based and offshore wind projects. *Graphic by NREL*

NREL Technology Management and Support

Point of contact: Brian Smith, Brian.Smith@nrel.gov WETO.5.1.0.401

Broadening Wind Research Impact with Skillful Technology Management and Support

The Technology Management and Support project enables all activities in NREL's wind energy R&D portfolio and provides strategic support to WETO and other DOE national laboratories and technology partners supporting the program. Achievements include serving in a strategic leadership role of the IEA Wind Technology Collaboration Programme, overseeing NREL's research presentations and posters, guiding conference panel participation, developing and delivering the annual NREL wind accomplishments report, and producing ongoing communications products, such as *The Leading Edge*, NREL's wind portfolio newsletter.

NREL plays a critical strategic role in the International Energy Agency Wind Technology Collaboration Programme fostering an international dialog on wind energy research and development.
Photo courtesy of NREL

Significance and impact:

Skillful project management through this task enables all activities in NREL's broad wind energy research and development portfolio to directly support the WETO mission and lead the nation's efforts in early-stage R&D, helping develop and deploy technologies that enable growth of the U.S. wind industry, enhance U.S. competitiveness, increase U.S. energy security and independence, strengthen domestic manufacturing, and provide local economic opportunities across the country.

Communications Support

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Strategic Communications Amplify the Wind Energy Technologies Office Mission

The NREL communications team supports WETO and its efforts to reach its target audiences through project dissemination and amplification that leverage numerous tactics and channels. Achievements include creating interactive graphics for market report pages, writing web articles and event listings, coding and disseminating breaking news emails, providing strategic content guidance on priority web pages, and leading website animation improvement projects. The team also helps WETO organize events and manages the development process for the three largest publications of each year: the R&D Newsletter (fall and spring editions) and the U.S. chapter for the IEA Wind Technical Collaboration Programme Annual Report.

Significance and impact:

The NREL communications team amplifies WETO's mission by creating a variety of communications materials, such as fact sheets, technical reports, brochures, web content, newsletters, and social media posts, and disseminating them to relevant stakeholders. By delivering WETO news through a multitude of channels, the team increases stakeholder awareness of WETO's R&D priorities and fosters a greater understanding of the benefits of wind energy technologies.

Publications

Journal Articles

Alexander, Francis, Ann Almgren, John Bell, Amitava Bhattacharjee, Jacqueline Chen, Phil Colella, David Daniel, et al. 2020. "Exascale Applications: Skin in the Game." Philosophical Transactions of the Royal Society A: Mathematical, ***Physical and Engineering Sciences*** A 378, 2166 (January) 1–31. https://royalsocietypublishing.org/doi/10.1098/rsta.2019.0056.

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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/MP-6A42-76632 • May 2020

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