

# Distributed Wind Research Program Workshop Report

Workshop dates: August 26 and 27 and September 24, 2020

February 2021



## DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights**. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST NATIONAL LABORATORY

*operated by*

BATTELLE

*for the*

UNITED STATES DEPARTMENT OF ENERGY

*under Contract DE-AC05-76RL01830*

Printed in the United States of America

Available to DOE and DOE contractors from the  
Office of Scientific and Technical Information,  
P.O. Box 62, Oak Ridge, TN 37831-0062;  
ph: (865) 576-8401  
fax: (865) 576-5728  
email: reports@adonis.osti.gov

Available to the public from the National Technical Information Service  
5301 Shawnee Rd., Alexandria, VA 22312  
ph: (800) 553-NTIS (6847)  
email: [orders@ntis.gov](mailto:orders@ntis.gov) <<http://www.ntis.gov/about/form.aspx>>  
Online ordering: <http://www.ntis.gov>

## Acknowledgments

This report was prepared for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Wind Energy Technologies Office (WETO). The authors wish to thank Bret Barker, Patrick Gilman, and Liz Hartman of WETO and for their help in producing this report.

Report authors are Juliet Homer and Alice Orrell (Pacific Northwest National Laboratory); Jim Reilly, Heidi Tinneland, Ben Sigrin, Ian Baring-Gould, and Tyler Stehly (National Renewable Energy Laboratory), and Brian Naughton (Sandia National Laboratories).

The cover photo is courtesy of Roger Dixon, Skylands Renewable Energy, LLC.

## List of Acronyms

DER	distributed energy resource
DOE	U.S. Department of Energy
EV	electric vehicle
LCOE	levelized cost of energy
MIRACL	Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad
NRECA	National Rural Electric Cooperative Association
NREL	U.S. Department of Energy's National Renewable Energy Laboratory
O&M	operations and maintenance
RADWIND	Rural Area Distributed Wind Integration Network Development
WETO	U.S. Department of Energy's Wind Energy Technologies Office

## Table of Contents

<b>1.0 Introduction .....</b>	<b>1</b>
<b>2.0 Key Workshop Findings .....</b>	<b>2</b>
<b>3.0 Current Technology Research and Development Collaboration and Coordination Opportunities.....</b>	<b>4</b>
3.1 Controls and Modeling Tools .....	4
3.2 Cost and Valuation .....	4
3.3 Turbine Technology .....	5
<b>4.0 Potential Modes of Collaboration and Coordination.....</b>	<b>5</b>
4.1 Information Sharing and Forums .....	5
4.2 Broaden Network .....	6
4.3 Project-to-Project.....	6
<b>5.0 Future Technology Research and Development Opportunities.....</b>	<b>6</b>
5.1 Distributed Wind-Hybrid Power Plants .....	6
5.2 Tailored Solutions .....	7
5.3 Cost, Financing, and Valuation.....	8
5.4 Validation and Field Demonstration .....	8
5.5 Certification and Manufacturing .....	9
5.6 Miscellaneous .....	9
<b>6.0 Conclusion .....</b>	<b>9</b>
<b>Appendix A - Workshop Participants.....</b>	<b>A-1</b>
<b>Appendix B - Workshop Agenda .....</b>	<b>B-1</b>
<b>Appendix C - Project Profiles .....</b>	<b>C-1</b>

## List of Tables

Table 1. Workshop Participant Organizations.....	1
--	---

# 1.0 Introduction

The U.S. Department of Energy’s (DOE’s) Wind Energy Technologies Office (WETO) Distributed Wind Research Program seeks to enable wind technology as an affordable, accessible, and compatible distributed energy resource (DER) option for individuals, businesses, and communities.

WETO’s Distributed Wind Research Program includes national laboratory projects and partnerships with industry and academia. WETO organized the Distributed Wind Research Program Workshop to bring together laboratory and industry project stakeholders to achieve the following objectives:

1. **Educate** – Create a shared high-level understanding for the breadth of WETO’s distributed wind research
2. **Collaborate** – Facilitate coordination and collaboration between funding recipients to leverage resources
3. **Innovate** – Understand future research challenges and opportunities.

This workshop convened over 80 participants from the organizations listed in Table 1. Workshop participants were asked for their individual feedback based on their own expertise and experience. The findings presented below do not represent consensus findings on the part of participants but rather recurring themes from individual feedback provided during the workshop as summarized by the authors.

**Table 1. Workshop Participant Organizations**

Participant Type	Participants																
U.S. Government	U.S. Department of Energy Wind Energy Technologies Office U.S. Department of Agriculture Rural Energy for America Program																
U.S. DOE National Laboratories	Argonne National Laboratory Idaho National Laboratory Los Alamos National Laboratory National Renewable Energy Laboratory (NREL) Pacific Northwest National Laboratory Sandia National Laboratories																
Institutions and Associations	Electric Power Research Institute International Code Council-Small Wind Certification Council Iowa State University National Rural Electric Cooperative Association (NRECA) Solar Energy Trade Shows, LLC																
Distributed Wind Industry	<table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Bergey WindPower</td> <td style="width: 50%;">Primus Wind Power</td> </tr> <tr> <td>Buffalo Renewables Inc.</td> <td>QED Wind Power</td> </tr> <tr> <td>Carter Wind Turbines</td> <td>Sonsight Wind</td> </tr> <tr> <td>Ducted Wind Turbines</td> <td>Westergaard Solutions</td> </tr> <tr> <td>Eocycle Technologies Inc.</td> <td>Windurance</td> </tr> <tr> <td>Hoss Consulting</td> <td>Wind Consulting</td> </tr> <tr> <td>Intergrid</td> <td>Windward Engineering</td> </tr> <tr> <td>Pecos Wind Power</td> <td>XFlow Energy</td> </tr> </table>	Bergey WindPower	Primus Wind Power	Buffalo Renewables Inc.	QED Wind Power	Carter Wind Turbines	Sonsight Wind	Ducted Wind Turbines	Westergaard Solutions	Eocycle Technologies Inc.	Windurance	Hoss Consulting	Wind Consulting	Intergrid	Windward Engineering	Pecos Wind Power	XFlow Energy
Bergey WindPower	Primus Wind Power																
Buffalo Renewables Inc.	QED Wind Power																
Carter Wind Turbines	Sonsight Wind																
Ducted Wind Turbines	Westergaard Solutions																
Eocycle Technologies Inc.	Windurance																
Hoss Consulting	Wind Consulting																
Intergrid	Windward Engineering																
Pecos Wind Power	XFlow Energy																

This report summarizes key workshop findings, current technology research and development collaboration and coordination opportunities, potential modes of collaboration and coordination, and future technology research and development opportunities. In addition, Appendix A provides a complete participant list, Appendix B includes the workshop agenda, and Appendix C contains project profile descriptions of each major project in WETO’s Distributed Wind Research Program.

## 2.0 Key Workshop Findings

The WETO Distributed Wind Research Program spans a variety of research topics. Current research areas of particular interest include advanced controls and power system modeling tools, costs and valuation of distributed wind, distributed wind performance estimation and forecasting, and wind turbine technology optimization for DER applications. Workshop participants identified the following key collaboration and coordination opportunities for current research that would yield significant benefits:

- Modernize power system modeling tools to improve distributed wind's representation and valuation in tools and improve modeling of wind applications in distribution system simulations, particularly the growing markets of distributed wind hybrids and microgrids.
- Understand, model, and work to reduce distributed wind costs—particularly balance-of-station costs—but also characterize and understand the value of distributed wind beyond levelized cost of energy (LCOE).
- Collaborate on common platforms for power electronics to enable plug-and-play integration with the grid and other DERs.

Specific modes of collaboration identified focused on information sharing and establishing collaboration forums, broadening the research network beyond typical distributed wind industry stakeholders, and direct project-to-project connections. Key modes of collaboration include the following:

- Share information, from data sets to lessons learned, through a centralized platform, a listserv discussion group, and forums and targeted meetings. Workshop participants acknowledged that non-business-sensitive collaboration and data sharing may have broad benefit to the industry.
- Engage representatives of other DER industries, particularly storage, solar PV, microgrid, and electric vehicles (EVs). To the extent EVs can be used for energy storage and be charged and discharged based on a utility signal, they can be considered DERs. As distributed wind-hybrid installations and multi-DER microgrids become more common, workshop participants stressed the importance of networking and coordinating research efforts with other DER industries.

In addition to collaboration opportunities and modes of collaborations for current research endeavors, workshop participants discussed future technology research and development opportunities. The key research categories participants identified include wind hybrids; developing tailored solutions for customers; cost, financing, and valuation; validation and field demonstration; and certification and manufacturing. Within those categories, specific future research opportunities identified include the following:

- Standardize power conversion, controls, and communication equipment for wind hybrids and explore development of standardized hybrid microgrids.
- Create tailored products and business models to support emerging markets and specific customer types to help grow the distributed wind market. Emerging markets identified include energy-intensive facilities such as data centers, grow houses, and cryptocurrency farms, and wind-to-fuel applications.
- Develop a clear articulation of why wind matters and how it fits in decarbonization strategies.

- Identify approaches to lower the cost of turbine model certification and address the challenge that, in some cases, certification inhibits innovation because technologies cannot be changed after certification costs are paid, without recertifying.

Workshop participants identified these research and collaboration opportunities as being crucial to support distributed wind market growth as the distributed wind and DER industries collaborate and innovate to respond to changing and evolving electric grid systems.

## 3.0 Current Technology Research and Development Collaboration and Coordination Opportunities

Workshop participants identified collaboration and coordination opportunities within the current Distributed Wind Research Program. Ideas are grouped below into common themes.

### 3.1 Controls and Modeling Tools

Advanced controls for distributed wind can improve grid operations and enable distributed wind technologies to provide grid services. Power system modeling informs technical and economic power system planning. Including advanced control capabilities in power system modeling increases the ability of researchers and developers to identify appropriate beneficial applications and locations of distributed wind. Workshop participants identified the following opportunities to collaborate and coordinate on research and development of controls and modeling tools:

- Modernize power system modeling tools to improve distributed wind's representation and valuation. For example, distributed wind models developed for GridLAB-D can be shared with OpenDSS model developers.
- Improve modeling of wind hybrids, microgrids, and other wind applications in distribution system simulations. Share data, code, and modeling approaches.
- Design advanced system controllers and power electronics that allow wind to provide valued grid support (i.e., synthetic inertia, rotor inertia, and reactive power support) and plug-and-play integration.
- Incorporate resource-forecasting tools into power system simulation modeling, valuation and cost modeling, and project development tools used by utilities and developers to reduce uncertainty.

### 3.2 Cost and Valuation

Distributed wind cost data are important for many aspects of distributed wind research and development. Valuation is the process of determining the relative worth, utility, or importance of distributed wind in different applications. Valuation includes cost, because cost can be a value judgment, but can also include nonmonetary components. Workshop participants identified the following cost and valuation collaboration and coordination opportunities:

- Understand, model, and work to reduce balance-of-station costs (e.g., permitting, labor, site preparation, foundation construction, electric infrastructure, and tower installation).
- Share hardware costs, balance-of-station costs, operation and maintenance costs, power curves, and other techno-economic attributes for cost modeling, analysis, and development purposes.
- Develop a process for characterizing the temporal alignment of resource availability, turbine performance, and customer and system load at a location, and this relationship's impact on wind valuation.
- Characterize and understand the value of distributed wind beyond LCOE, including the value of resilience and community development. Understand how uncertainty and risk factors can affect that value.
- Share valuation tools and results between projects.

### 3.3 Turbine Technology

Workshop participants identified the following collaboration and coordination opportunities concerning distributed wind technology:

- Collaborate on turbine component innovation (e.g., towers, foundations, blades, and generators) and common platforms for power electronics.
- Explore turbine manufacturer coordination for establishing common parts suppliers for components such as towers and blades, and even specific parts, such as rare earth magnets, so each distributed wind turbine manufacturer does not have to create its own supplier network.
- Recommend improvements to the certification process, especially concerning integration requirements and certification of inverters.

## 4.0 Potential Modes of Collaboration and Coordination

After identifying collaboration and coordination opportunities, workshop participants brainstormed modes of collaboration. The following ideas, grouped by similarity, were suggested as specific ways to collaborate, both within WETO's Distributed Wind Research Program and with outside researchers and potential collaborators.

### 4.1 Information Sharing and Forums

Workshop participants suggested the following ways to share information and expand collaboration and coordination:

- Establish an extensive distributed wind data and information sharing platform where data, project information, case studies, and modeling tools are collected and made available to researchers, developers, utilities, and government entities.
  - Make data sets available, including cost, deployment, and operations and maintenance (O&M) data.
  - Share case studies (both successes and lessons learned) and information on existing distributed wind installations, including distributed wind in hybrid and microgrid applications.
- Develop a plan for scheduled and structured sharing of work products and project deliverables for current and future projects.
- Develop and share individual project or initiative websites (e.g., [NRECA's Rural Area Distributed Wind Integration Network Development \[RADWIND\]](#) and [NREL's Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad \[MIRACL\]](#)).
- Share innovative business model approaches, including those for rural customers.
- Establish a listserv discussion group or online resource center, such as a Slack channel or a LinkedIn group, for coordination.
- Establish a discussion group to address opportunities to increase diversity, equity, and inclusion in distributed wind efforts.
- Establish a manufacturers' lessons-learned forum; include companies no longer in business.
- Organize presentations from project developers and owners to facilitate an honest assessment of what worked and what didn't.

- Develop an online permitting and zoning resource center.
- Organize follow-up workshops or Zoom meetings; propose cross-project, joint panel sessions at conferences, such as those of the American Clean Power Association, the Institute of Electrical and Electronics Engineers Power & Energy Society, and the Energy Systems Integration Group.

## 4.2 Broaden Network

As distributed wind-hybrid installations and multi-DER microgrids become more common, workshop participants identified the following suggestions to coordinate across those technologies:

- Identify storage and solar industry representatives and associations and engage them in the conversation.
- Initiate conversations with representatives and groups focused on other DERs, such as flexible loads, microgrids, and EVs. EVs qualify as DERs when used for energy storage that can be charged from and discharged to the distribution grid. Wind-powered EV charging—at homes, businesses, and along interstates—was also identified as an emerging market opportunity.
- Initiate conversations with representatives and groups working on wind-to-fuel applications, such as wind generated hydrogen gas for fuel cells.

## 4.3 Project-to-Project

Workshop participants recommended the following project-to-project and manufacturer-to-manufacturer coordination efforts:

- Establish cross-project working groups around research areas of common interest, such as valuation or resilience metrics.
- Organize targeted cross-project coordination. For example, the distributed wind performance estimation and forecasting research of the [Tools Assessing Performance](#) project could be extended to an international data set. The international data set could serve as an input to planning tools used by the military or international aid organizations to evaluate the use of a deployable wind turbine to their location of interest as part of the [Disaster and Defense Deployable Turbine project](#).
- Explore collaborative procurements by wind turbine manufacturers.
- Organize structured cross-project advisory board events.

# 5.0 Future Technology Research and Development Opportunities

This section focuses on future research opportunities for technical topics that participants selected to discuss during the workshop. These research opportunities are either direct suggestions from individual workshop participants or are gleaned from the visions of project success participants shared during a brainstorming activity.

## 5.1 Distributed Wind-Hybrid Power Plants

Interest in and deployment of wind-hybrid power plants are increasing. Workshop participants identified the following specific research opportunities for wind hybrids:

- Standardize power conversion, controls, and communication equipment.
- Research multisource inverters for hybrid power plants.
- Develop integrated forecasting for wind hybrids.
- Develop an integrated storage sizing methodology for wind hybrids to achieve desired technical and economic outcomes.
- Explore the development of standardized hybrid-powered microgrids.
- Explore business models and market structures that realize the value of hybrids, including peak shaving and ancillary service participation.
- Understand the considerations, benefits, and challenges of AC hybrids versus DC hybrids.
- Research hybrid grid integration issues and solutions. Create standardized and open-sourced protocols for integration of distributed wind with distribution management systems and microgrid controllers.
- Develop advanced controller testing for wind and wind-hybrid technologies.
- Research the value of hybrids to owners and utilities, accounting for the increased combined capacity factor resulting from resource diversity.
- Specifically focus on wind-storage hybrids. Consider ways to reduce cost and increase performance of wind-storage hybrids to improve cost effectiveness. Research the implications, opportunities, and issues for wind-storage hybrids afforded by Federal Energy Regulatory Commission Order 2222 which allows DERs to participate in wholesale markets.

## 5.2 Tailored Solutions

Workshop participants discussed how tailored solutions could help grow the distributed wind market and identified the following research opportunities for tailored solutions:

- Develop technology solutions tailored to customer types.
- Explore the development of turnkey solutions (i.e., products constructed to be sold to a buyer as a complete product ready for immediate use) combined with plug-and-play features and open-source software and controls.
- Consider electrification research to address the market opportunity of wind-powered EV charging stations at homes, businesses, and along interstates.
- Develop tailored distributed wind solutions for achieving resilience goals of utilities, communities, or other stakeholders. A resilience goal may be to power critical loads for a specified duration during a grid outage.
- Establish tailored products and business models to support the following emerging markets:
  - energy-intensive industries (e.g., data centers, grow houses, and cryptocurrency farms)
  - wind-to-fuel applications
  - states and companies with renewable energy and decarbonization targets
  - educational facilities, such as schools and community colleges
  - isolated communities not connected to a central grid (e.g., Alaskan villages)

### 5.3 Cost, Financing, and Valuation

Workshop participants identified the following specific research opportunities around costs, financing, and valuation:

- Support research that will help reduce turbine hardware, installation, and O&M costs.
- Develop business models that include financing options for customers.
- Establish quantifiable metrics to demonstrate benefits afforded by distributed wind. Metrics could provide a basis for investment.
- Develop a decision-support tool for utilities, developers, and communities that characterizes grid value, utility cost and benefit, and the community and nontraditional values of potential projects.
- Develop a compendium of examples where non-LCOE value streams were realized or were the basis of investment decisions.
- Develop and make available a set of examples of where distributed wind has been used to a) help support the system during emergencies when expensive diesel generators would otherwise be used, b) support black start, c) power microgrids, or d) reduce the necessary size of energy storage.
- Develop a clear articulation of why distributed wind matters and how it fits in decarbonization strategies.
- Characterize the policies that have the greatest impact on the cost and value of distributed wind and evaluate the impacts of policy instability on the distributed wind market.

### 5.4 Validation and Field Demonstration

While the technology research and development opportunities outlined in this report are broadly available to industry stakeholders, workshop participants also identified the following specific validation and field demonstration ideas for distributed wind:

- Implement expanded (and supported) turbine and component testing for certification, reliability (fatigue), and operational experience in different wind resources.
- Integrate and test wind in existing microgrid control systems.
- Perform operation testing of small-scale innovative power systems including wind (i.e., small microgrid and nesting of multiple microgrids).
- Use controlled laboratory environments (i.e., hardware in the loop and controlled loads) for controllers and grid services modeling.
- Investigate how turbine control and turbine systems can be part of integration control.
- Document advanced communications (i.e., turbine to a controller and turbine to a utility).
- Develop and test new controls for multiple distributed wind turbines (and other DERs) on a weak grid.
- Identify realistic test sites for field validation of advanced technology.
- Support implementation of and share results from data collection of field demonstrations.

## 5.5 Certification and Manufacturing

Workshop participants identified the following specific research opportunities for certification and manufacturing:

- Work toward lowering the cost of certification. As one example, distributed wind turbine manufacturers could set up a retainer with certification bodies as a group.
- Support development of clear and appropriate rules around what triggers a new certification.
- Address the challenge that, in some cases, certification inhibits innovation because technologies cannot be changed after certification costs are paid, without recertifying.
- Improve the ways in which laboratory research reaches and can be used by the distributed wind and DER industries.
- Coordinate on advancements in turbine performance and condition monitoring, including faults.

## 5.6 Miscellaneous

Over the course of the workshop, participants generated many ideas, some of which are not easily captured under general themes. Those miscellaneous research ideas and opportunities include the following:

- Develop a standard way to calculate ice and blade throw that small wind installers and developers can use with customers and permitting authorities.
- Compile and publish—in a readily accessible way, such as through [WINDEXchange](#)—information and fact checking about wind, that addresses some of the common misinformation and myths.
- Develop wind resource and siting assessment tools that provide features such as clear ratings as to whether a location is a good or poor place to build and optimal turbine location and tower selection.
- Develop recommendations, tools, models, examples, and best practices for addressing technical challenges resulting from grid interconnection requirements.

## 6.0 Conclusion

WETO facilitated the Distributed Wind Research Program Workshop to promote collaboration across the program and to identify future research challenges and opportunities.

This report provides reference material for both WETO-funded distributed wind research projects and interested stakeholders on key research topics, which topics would benefit from collaboration and coordination, and potential modes of collaboration.

WETO appreciates the time and input provided by all workshop participants. As electric grid systems continue to evolve, WETO looks forward to continued collaboration and innovation in the Distributed Wind Research Program and with distributed wind and DER stakeholders.

## Appendix A - Workshop Participants

Name	Organization
Bouaziz Ait-Driss	Eocycle Technologies Inc.
Trevor Atkinson	Eocycle Technologies Inc.
Venkat Banunaryanan	National Rural Electric Cooperative Association
Ian Baring-Gould	NREL
Bret Barker	WETO
Sarah Barrows	PNNL
John Bell	INL
Mobolaji Bello	Electric Power Research Institute
Larry Berg	PNNL
Mike Bergey	Bergey WindPower
Parangat Bhaskar	NREL
Bishnu Bhattarai	PNNL
Cynthia Bothwell	WETO
Paul Breakman	National Rural Electric Cooperative Association
Ian Brownstein	Xflow Energy
Matt Carter	Carter Wind Turbines
Dan Clunies	Windurance
Patrick Conry	LANL
Scott Dana	NREL
Dean Davis	Windward Engineering
Shannon Davis	WETO
Phillip J. Dougherty	WETO
Caroline Draxl	NREL
Dmitry Duplyakin	NREL
Brandon Fitchett	Electric Power Research Institute
Scott Fouts	QED Wind Power
Jian Fu	WETO
Jake Gentle	INL
Patrick Gilman	WETO
Josh Groleau	Pecos Wind Power
Luis Gutierrez	Unknown
Will Hershey	Pecos Wind Power
Juliet Homer	PNNL
Jenn Jenkins	Solar Energy Trade Shows, LLC
Tony Jimenez	NREL
Maria Kanevsky	National Rural Electric Cooperative Association
Padma Kasthurirangan	Buffalo Renewables Inc
Patrick Kelly	Hoss Consulting
Anne Kimber	Iowa State University

---

<b>Name</b>	<b>Organization</b>
Ken Kotalik	Primus Wind Power
Rao Kotamarthi	ANL
Venkat Krishnan	NREL
Eric Lantz	NREL
Richard Legault	Eocycle Technologies Inc.
Michael Leitman	National Rural Electric Cooperative Association
Alex Lemke	NREL
Rod Linn	LANL
Rocky McIntosh	Sonsight Wind
Brian Naughton	Sandia
Matt Nelson	LANL
Charles Newcomb	Hoss Consulting
Alice Orrell	PNNL
Quentin Pagnier	Pecos Wind Power
Paul Pavone	Ducted Wind Turbines
Caleb Phillips	NREL
Nick Pilot	Electric Power Research Institute
Robert Preus	NREL
Raj Rai	PNNL
Jim Reilly	NREL
Andrew Reiman	PNNL
Craig Rieger	INL
Mike Robinson	NREL
Paul Rowan	Windurance
Nate Schmitt	Hoss Consulting
Ron Schoff	Electric Power Research Institute
Will Shaw	PNNL
Lindsay Sheridan	PNNL
Ben Sigrin	NREL
Brian Smith	NREL
David Snowberg	NREL
Max Stapel-Kalat	INL
Tyler Stehly	NREL
Ben Strom	Xflow Energy
Brent Summerville	International Code Council-Small Wind Certification Council
Heidi Tinnensend	NREL
Zhaoyu Wang	Iowa State University
Jiali Wang	ANL
Venus Welch-White	U.S. Department of Agriculture Rural Energy for America Program
Carsten Westergaard	Westergaard Solutions
Brad Whipple	INL

---

---

<b>Name</b>	<b>Organization</b>
Felipe Wilches-Bernal	Sandia
Rob Wills	Intergrid
Tom Wind	Wind Consulting
Sagi Zisman	NREL

---

ANL = U.S. Department of Energy's Argonne National Laboratory  
INL = U.S. Department of Energy's Idaho National Laboratory  
LANL = U.S. Department of Energy's Los Alamos National Laboratory  
NREL = U.S. Department of Energy's National Renewable Energy Laboratory  
PNNL = U.S. Department of Energy's Pacific Northwest National Laboratory  
Sandia = U.S. Department of Energy's Sandia National Laboratories  
WETO = U.S. Department of Energy's Wind Energy Technologies Office

---

## **Appendix B - Workshop Agenda**

# Distributed Wind Research Program Workshop

Photo Credit: Lake Region Electric Cooperative

U.S. DEPARTMENT OF ENERGY (DOE) WIND ENERGY TECHNOLOGIES OFFICE (WETO)

## WORKSHOP AGENDA

AUGUST 26-27, 2020 – ZOOM ONLINE

Wednesday, August 26, 2020

0700-0755 PDT	<p><b>Welcome Opening Session</b></p> <ul style="list-style-type: none"> <li>• Zoom logistics</li> <li>• Workshop format</li> <li>• Workshop expectations</li> <li>• DOE WETO Introduction</li> <li>• Around the Zoom introductions</li> </ul>
	<p><b>Project Sessions Discussion Guidance</b></p> <ul style="list-style-type: none"> <li>• What are the key areas of research overlap?</li> <li>• What are key areas/opportunities for future coordination?</li> <li>• What are potential modes of operation for future coordination, i.e., what specific things can we do to facilitate future collaboration (e.g., put monthly, quarterly, or annual meetings on the calendar)?</li> </ul>
0800-0855 PDT	<p><b>Project Session #1: Wind Innovations for Rural Economic Development (WIRED) &amp; Rural Cooperatives</b></p> <p><i>Session Lead: Juliet Homer, juliet.homer@pnnl.gov</i></p> <p>Attend this session to discuss how WIRED projects and other projects interested in working with rural cooperatives and communities could collaborate.</p>
0855-0905	<b>BREAK</b>
0905-1000 PDT	<p><b>Project Session #2: Tools Assessing Performance (TAP)</b></p> <p><i>Session Lead: Heidi Tinneland, heidi.tinneland@nrel.gov</i></p> <p>Attend this session to learn about how you could collaborate with TAP and other projects also interested in TAP research.</p>
1005-1100 PDT	<p><b>Project Session #3: Defense &amp; Disaster Deployable Turbine (D3T)</b></p> <p><i>Session Lead: Brian Naughton, bnaught@sandia.gov</i></p> <p>Attend this session to learn about how you could collaborate with D3T and other projects also interested in D3T research.</p>
1100-1110 PDT	<b>BREAK</b>
1110-1205 PDT	<p><b>Project Session #4: Distributed Wind Cost Modeling, Valuation, and Analysis</b></p> <p><i>Session Lead: Eric Lantz, eric.lantz@nrel.gov</i></p> <p>Attend this session to discuss collaboration opportunities for reducing costs of distributed wind energy systems, data gaps, and approaches to valuing distributed wind.</p>
1205-1300 PDT	<p><b>Project Session #5: Manufacturers Forum</b></p> <p><i>Session Lead: Ian Baring-Gould, ian.baring-gould@nrel.gov</i></p> <p>Attend this session to discuss collaboration opportunities around supply chain sourcing, design standards, certification, and common needs of U.S. manufacturing.</p>

Thursday, August 27, 2020

	<b>Technical Sessions Discussion Guidance</b> <ul style="list-style-type: none"><li>• What are the challenges and opportunities with each technical topic?</li><li>• What project collaboration on these technical topics can effectively address these challenges and opportunities?</li><li>• If collaboration is not appropriate, can any of the projects be better coordinated to avoid duplication of work and leverage resources?</li></ul>
0700-0755 PDT	<b>Technical Topic #1: Hybrid Systems</b> <i>Session Lead: Jim Reilly, james.reilly@nrel.gov</i> How can wind be part of hybrid systems such as "wind +" and "wind to X (e.g., hydrogen, EVs)"?
0800-0855 PDT	<b>Technical Topic #2: Emerging Markets and Market Expansion</b> <i>Session Lead: Ben Sigrin, benjamin.sigrin@nrel.gov</i> What are the markets in 2 years, 5 years, and 10 years? Where are the expansion opportunities - with agricultural end-users, with commercial and industrial behind-the-meter end-users?
0855-0905 PDT	<b>BREAK</b>
0905-1000 PDT	<b>Technical Topic #3: Business Models &amp; Turnkey Solutions</b> <i>Session Lead: Juliet Homer, juliet.homer@pnnl.gov</i> What are key untapped value propositions? How do we make distributed wind easier to adopt?
1005-1100 PDT	<b>Technical Topic #4: Validation and Field Demonstration</b> <i>Session Lead: Ian Baring-Gould, ian.baring-gould@nrel.gov</i> What distributed wind and wind-hybrid technologies require lab-supported validation? What lab and industry research would benefit from demonstration at a real-world site? What case studies could inform future, replicable system designs and/or business models?

Thursday, September 24, 2020

	<b>Closing Session</b> Save the date. Stay tuned for details!
--	--

# Distributed Wind Research Program Workshop

Photo Credit: Lake Region Electric Cooperative

U.S. DEPARTMENT OF ENERGY (DOE) WIND ENERGY TECHNOLOGIES OFFICE (WETO)

WORKSHOP CLOSING SESSION AGENDA

SEPTEMBER 24, 2020 – ZOOM ONLINE

Thursday, September 24, 2020

0700-0720 PDT	<p><b>Welcome Opening Session</b></p> <ul style="list-style-type: none"> <li>• Zoom logistics, review agenda, desired outcomes</li> <li>• DOE WETO Welcome</li> <li>• Sharing is Caring</li> <li>• Ice Breaker</li> </ul>
0720-0845 PDT	<p><b>Report Back</b>  <i>Session Lead: Juliet Homer, juliet.homer@pnnl.gov</i>                      Laboratory staff will report back to attendees the key issues and collaboration opportunities identified during the August workshop sessions.</p>
0845-0915 PDT	<p><b>Report Back Breakout Discussions</b>  <i>Session Lead: Heidi Tinneland, heidi.tinneland@nrel.gov</i>                      In breakout groups, attendees will discuss the presented report back summaries to confirm laboratory staff captured the right issues and didn't miss anything major, and to identify what opportunities are most important.</p>
0915-0925 PDT	<p><b>BREAK</b></p>
0925-0935 PDT	<p><b>Diversity, Equity, and Inclusion Moment</b>  <i>Session Lead: Alice Orrell, alice.orrell@pnnl.gov</i></p>
0935-1005 PDT	<p><b>Wild Success</b>  <i>Session Lead: Eric Lantz, eric.lantz@nrel.gov</i>                      We will brainstorm what wild success would look like for your project and collaboration opportunities and for the distributed wind industry.</p>
1005-1045 PDT	<p><b>Next Steps to Achieve Wild Success and Collaboration</b>  <i>Session Lead: Juliet Homer, juliet.homer@pnnl.gov</i>                      We will review and discuss the specific collaboration opportunities and actions that were proposed during the August workshop sessions.</p>
1045-1100 PDT	<p><b>Wrap Up, Thank You, and Next Steps</b></p> <ul style="list-style-type: none"> <li>• Workshop deliverables</li> <li>• Thank you!</li> <li>• Check-out activity</li> </ul>

## Appendix C - Project Profiles

# Distributed Wind Research Program Workshop: Project Profile Booklet

U.S. Department of Energy  
Wind Energy Technologies Office  
Distributed Wind Program  
August 26 & 27, 2020 &  
September 24, 2020

## Contents

1	Introduction .....	1
1.1	Purpose of Project Profile Booklet .....	1
1.2	Distributed Wind Research Program Overview .....	1
2	Competitiveness Improvement Project .....	3
2.1	Pecos Wind Power: System Optimization of Rotor-Nacelle Assembly for 85 kW Wind Turbine .....	3
2.2	QED Wind Power: Certification Testing of the QED Wind Power PHX20 .....	4
2.3	Primus Wind Power: Optimizing AIR Breeze with Innovative Controller .....	4
2.4	XFlow Energy Company: A Robust and Efficient 20 kW Vertical-Axis Wind Turbine for Remote Micro-Grids.....	5
2.5	Sonsight Wind: 3.5 kW Turbine System Optimization .....	5
2.6	Windward Engineering: Pre-Prototype Development of a Medium Size Wind Turbine .....	6
2.7	Windurance: A 480V, 3 Phase, Platform for Wind Turbine Power Conversion.....	6
2.8	Matric: Manufacturing a 25 kW Wind Inverter.....	7
3	Wind Innovations for Rural Economic Development (WIRED) .....	8
3.1	Iowa State University: Optimal Operation and Impact Assessment of Distributed Wind for Improving Efficiency and Resilience of Rural Electricity Systems .....	8
3.2	Electric Power Research Institute (EPRI): Wind Intelligently Integrated into Rural Energy Systems (WIRES) .....	9
3.3	National Rural Electric Cooperative Association (NRECA): Rural Area Distributed Wind Integration Network Development (RADWIND) .....	9
3.4	Bergey Windpower: Business Model for Rural Cooperative Distributed Wind Microgrids.....	10
4	National Laboratory Based Research Activities .....	11
4.1	Sandia National Lab: Defense and Disaster Deployable Turbine (D3T) .....	11
4.2	National Renewable Energy Laboratory: Tools Assessing Performance (TAP).....	11
4.3	National Renewable Energy Laboratory: Distributed Wind Energy Modeling and Analysis .....	12
4.4	National Renewable Energy Laboratory: Microgrids, Infrastructure Resilience and Advanced Controls Launchpad (MIRACL) .....	12
4.4.1	Pacific Northwest National Laboratory: Improving Distributed Wind Valuation and Representation in Tools .....	13
4.4.2	National Renewable Energy Laboratory: Advanced Controls for Distributed Wind.....	13
4.4.3	Idaho National Laboratory: Distributed Wind Resilience and Cyber Security .....	14
5	Complementary Programs – Small Business Innovation Research.....	16
5.1	Pecos Wind Power: Tilt-Up Tower and Installation System to Reduce the Cost of Distributed Wind Turbines.....	16

## 1 Introduction

The U.S. Department of Energy's (DOE's) Wind Energy Technologies Office (WETO) with support from Pacific Northwest National Laboratory (PNNL) prepared the *Distributed Wind Research Program Project Profiles Booklet* to provide a standardized snapshot of each WETO-sponsored project in the Distributed Wind Research Program.

### 1.1 Purpose of Project Profile Booklet

The primary purpose of the Project Profile Booklet is to allow attendees to identify projects and topics of interest in advance of the workshop to guide their participation in the sessions described in the agenda. Secondly, the workshop organizer developed the Project Profile Booklet to 1) avoid having each sponsored project present their project via PowerPoint in a virtual workshop format; 2) provide attendees with easily accessible basic information about each sponsored project for future reference; and 3) facilitate communication and coordination between projects.

The workshop organizers thank the Principal Investigators (PIs) who took the time to thoughtfully complete their Project Profile Template.

### 1.2 Distributed Wind Research Program Overview

WETO differentiates distributed wind from land-based and offshore wind in that the latter provide power and services primarily to the transmission grid at utility scale. Distributed wind, by contrast, typically provides power for on-site demand or to support local distribution networks.

Accordingly, distributed wind (DW) is defined in terms of the technology's application, rather than its size. The following attributes are used to characterize wind systems as "distributed":

- Proximity to End Use: Wind turbines that are installed at or near the point of end use for the purposes of meeting on-site energy demand or supporting the operation of the existing distribution grid.
- Point of Interconnection: Wind turbines that are connected to the distribution grid, or are connected to a microgrid (distribution connected or isolated).

Distributed wind energy systems are commonly installed at, but are not limited to, residential, agricultural, commercial, industrial, and community sites. The size of the turbines can range from a 5-kW turbine at a home to one or more multi-megawatt turbines at a manufacturing facility.

In the United States, there is approximately 1.1 GW of distributed wind capacity installed as of 2019, with installations in all 50 states. There is significant potential for expanded application for both larger and smaller DW systems. Larger DW systems are finding uses at commercial and industrial sites and, in conjunction with other distributed energy resources (DERs), as providers of balancing support for local grid operations and added resilience to critical infrastructure (as back-up power) when bulk power systems may be interrupted. Smaller DW systems may be designed for residential applications, small agricultural or commercial operations, or rapid deployment to power isolated microgrids in support of military operations, disaster relief, and other applications. The Office's support for research and innovation, in collaboration with industry partners, has contributed to more efficient designs and significant LCOE reductions, and in some cases, by 50% or more.

Today, DW provides important benefits to many users, often in rural and remote areas. However, the realization of DW's greater potential nationwide is impeded by a number of challenges. Because DW turbines are not modular or currently manufactured at an industrial scale, its equipment costs are often higher than other DERs such as solar PV. A lack of repeatability in DW projects raises balance-of-system costs, particularly for permitting and interconnection to local distribution networks. Because state-of-the-art methodologies used by large utility wind plant developers for accurate wind resource assessment are too costly and time consuming for DW projects, current DW site assessments are often based on "rules-of-thumb," resulting in errors in system performance forecasting, and eroding consumer and investor confidence. Similarly, accurately and cost-effectively forecasting DW system performance is critical for informing the controls required for hybrid system operation and optimization.

WETO's approach to supporting the realization of DW's technical potential includes industry partnerships and national laboratory-based research targeting reductions in the higher cost-contributing elements of DW systems and to improve system performance. More specifically, work includes:

- Standardization of balance-of-plant (all elements of a distributed wind plant outside of the turbine and tower systems themselves) and installation to reduce capital costs
- Improving turbine performance to cost-effectively increase energy production
- Improving turbine performance forecasts to reduce energy production risk
- Developing low-cost active monitoring, controls, and communication technologies to improve reliability and allow for the provision of needed grid services and integration with other DERs
- Understanding of the market conditions that may foster or constrain distributed wind technology development and deployment while helping to inform potential pathways for realizing lower installed costs and lower cost of energy

## 2 Competitiveness Improvement Project

Launched in 2013, the Competitiveness Improvement Project (CIP) supports manufacturers of distributed wind technology—typically small and medium scale wind turbines—through competitively-awarded, cost-shared projects aiming to: 1) optimize designs for increased energy production and grid support; 2) test turbines and components to national standards to verify performance and safety; and 3) develop advanced manufacturing processes to reduce hardware costs. Beyond funding support, awardees can receive technical assistance from the National Renewable Energy Laboratory (NREL) to improve their turbine designs and testing plans. Since 2013, NREL has awarded 44 subcontracts to 23 companies, totaling over \$10 million of funding, while leveraging over \$5 million in additional private-sector investment.

Mirroring a trend seen with larger wind turbines, many of these projects are developing small or medium-size wind turbines with larger rotors, allowing them to capture more energy even in areas with lower wind speeds. These larger rotors create a need to reconsider the drive trains, turbine controls, and support structures, not only to increase energy production, but also manage loads and reduce system weight and cost. Other trends among these projects are integrated energy storage and advanced controls for hybrid energy systems in order to provide grid support services and resiliency.

The CIP supports WETO's goals to make wind energy cost competitive, improve interoperability with other distributed energy resources, and increase the number of wind turbine designs certified to national testing standards. Project profiles for active CIP projects received in advance of the workshop follow.

### 2.1 Pecos Wind Power: System Optimization of Rotor-Nacelle Assembly for 85 kW Wind Turbine

**Project PI:** Josh Groleau, josh@pecoswindpower.com, 207-745-2231

**Project Team:** Pecos Wind Power

#### **Short Project Description:**

Through NREL's CIP, Pecos Wind Power is developing an 85 kW HAWT. By leveraging a large 30 m rotor, we aim to bring lower LCOE to lower wind speed markets.

#### **Anticipated outcomes / deliverables:**

1. Design and analysis of the rotor-nacelle-assembly of an 85 kW distributed wind turbine.
2. Loads analysis and optimization of our 85 kW turbine.

#### **Collaboration interests:**

1. Collaboration with other turbine OEMs on standardized components (foundations, towers, power electronics, etc.).
2. Collaboration with utilities, distributors, other OEMs on go-to-market strategies for 50-100 kW distributed wind turbines.

## 2.2 QED Wind Power: Certification Testing of the QED Wind Power PHX20

**Project PI:** Scott Fouts, scott.fouts@qedwindpower.com, 740-601-3959

**Project Team:** QED Wind Power LLC

### **Short Project Description:**

The goal is to successfully conduct and complete testing of the PHX20 to national standards to verify performance and safety.

### **Anticipated outcomes / deliverables:**

1. Verify Loads Analysis;
2. Complete Duration Testing;
3. Develop Official Power Curve

### **Collaboration interests:**

1. Small wind turbine developers interested in the certification process

## 2.3 Primus Wind Power: Optimizing AIR Breeze with Innovative Controller

**Project PI:** Ken Kotalik

**Project Team:** Ken Kotalik, Ketter Ulrich, Kurt Bankord, Ken Portolese, Thornwave Labs of NC, NREL and other support members.

### **Short Project Description:**

NREL funding for the optimization of the AIR micro turbine will enable Primus Wind Power to reduce overall manufacturing costs, improve performance and long-term reliability with a new circuit board and power electronics, consisting of hardware and firmware advances.

Hardware advances will consist of more modern componentry with advanced capabilities, including wireless communication and lithium battery technology seamless compatibility. Firmware advances will consist of more sophisticated turbine control (with enhanced features such as “Quiet” and “Power” modes), remote monitoring and diagnostics.

### **Anticipated outcomes / deliverables:**

Greater world-wide market share to a larger scope of both commercial and consumer-based industries, in addition to increased reliability and power output. Increased compatibility in Marine market with Lion Ion integration and ability to change settings and update firmware via wireless application. Allow for more efficient manufacturing and lower cost with enhanced capabilities.

### **Collaboration interests:**

- Existing customers looking for upgraded power electronics and communication in the thousands of AIR turbines in the small wind market deployed all over the world.
- Wind for Schools System developers

- DOD and Oil and Gas Hybrid systems integrators
- Marine customers interested in the communication and diagnostic capabilities of the new turbine power electronics
- Telecom providers

## 2.4 XFlow Energy Company: A Robust and Efficient 20 kW Vertical-Axis Wind Turbine for Remote Micro-Grids

**Project PI:** Ian Brownstein, ian@xflowenergy.com, 617-548-9301

**Project Team:** XFlow Energy Company

### **Short Project Description:**

XFlow Energy Company is developing a 20 kW, H-rotor vertical-axis wind turbine (VAWT) to address the needs of remote regions. Typically served by diesel generators, electricity costs of remote communities in northern latitudes and on islands often exceed \$0.40/kWh. XFlow's turbine is designed to address the high costs of wind project logistics in these markets, including transportation, installation, and maintenance.

### **Anticipated outcomes / deliverables:**

This pre-prototype development project will retire many of the remaining techno-economic risks of the XFlow VAWT, including blade fatigue minimization and optimizing rotor hub, power transmission, tower and DC-grid interface electronics for reduced LCOE. The result of the effort will be an updated, lower-cost full-scale design ready for prototype testing.

### **Collaboration interests:**

1. PM generator manufacturers
2. Certification bodies
3. Turbine installers and maintenance contractors
4. Project developers

## 2.5 Sonsight Wind: 3.5 kW Turbine System Optimization

**Project PI:** Devon R McIntosh, devon@sonsightwind.com, 301-802-7460

**Project Team:** Sonsight Wind, Appalachian State University Small Wind Research and Demonstration Site

### **Short Project Description:**

Sonsight Wind has been developing a long-blade, low-rpm 3.5 kW HAWT to decrease levelized cost of energy by increasing energy production and decreasing turbine and installation costs. The turbine is designed around a novel permanent generator and the project involves optimization of the generator and the turbine electronics and an update of the turbine frame.

### **Anticipated outcomes / deliverables:**

1. Increased generator torque;
2. Improved turbine control;
3. Demonstrate consistently better power output and energy generation

**Collaboration interests:**

Microgrid system integrators with interest in developing a standardized interface for SWT's where the turbine uses its own onboard MPPT algorithm and electronics to determine desired power output and communicates this to the microgrid interface via an analog signal such as a voltage level (maybe 0 - 3.3 VDC or 0 - 5 VDC), such that the interface's power input applies the corresponding load level to the turbine's DC output.

## 2.6 Windward Engineering: Pre-Prototype Development of a Medium Size Wind Turbine

**Project PI:** Dean Davis, ddavis@windwardengineering.com, 801-372-9251

**Project Team:** Windward Engineering, RRD Engineering

**Short Project Description:**

Windward Engineering is proposing to develop a pre-prototype, 50-65 kW scale wind turbine design. We plan to leverage our extensive background in designing, manufacturing, selling, maintaining, testing, and certifying numerous wind turbine designs over the past three decades to produce a design with a targeted levelized cost of energy (LCOE) of \$0.147/kWh or less.

**Anticipated outcomes / deliverables:**

The proposed pre-prototype design exhibits a classic architecture in many ways – three-bladed, horizontal axis, induction generator, downwind, free yaw – while the project will investigate some less common but not unorthodox options. These include trade-off studies between full-span pitch control and pitchable tip brakes, and a decision on rotor size weighing increased energy capture against loads.

**Collaboration interests:**

Existing wind turbine component suppliers for blades, towers, and other structural components, Also new wind turbine component suppliers for components such as the controller, power electronics, and pitch controller.

## 2.7 Windurance: A 480V, 3 Phase, Platform for Wind Turbine Power Conversion

**Project PI:** Paul Rowan, prowan@windurance.com, 412-424-8905

**Project Team:** National Renewable Energy Laboratory

**Short Project Description:**

According to at least five Wind Turbine OEMs, there is currently no Wind System Power Conversion component that is certified to applicable standards for use in the United States Distributed Wind Energy market. The absence of a certified product poses a significant barrier to Distributed Wind market penetration for these, and other prospective OEMs, and developers. This project offers to remove that

barrier by developing and obtaining third party Certification for Wind System Power Conversion equipment. With investment added through an NREL Subcontract, leveraging existing designs of Intergrid LLC, of Temple, NH, with the support from five Wind Turbine OEMs, and combining existing Windurance experience and designs for real-time control processors and power conversion, Windurance proposes to develop and to certify a 480V, 3 Phase, distributed wind system specific power conversion platform in 80kW and 160kW rated configurations.

**Anticipated outcomes / deliverables:**

1. Design Verification of Intergrid's existing 3 phase inverter, adding converter features
2. Third Party Certification to UL1741/IEEE1547 and UL6142
3. Improved efficiency compared to IGBT based drives
4. Lower Cost than the typical Industrial Drive implementation

**Collaboration interests:**

Wind Turbine OEMs

[2.8 Matric: Manufacturing a 25 kW Wind Inverter](#)

**Project PI:** Walter Coxson, wcoxson@matric.com, 814-677-0716

**Project Team:** Matric Limited, Windurance, Intergrid, LLC

**Short Project Description:**

Presently, there are no certified turbine power electronics solutions that can be used for the US distributed wind market. Building on prior CIP work, this project will bring Intergrid's innovative 25 kW wind inverter to full commercial production to meet the needs of US wind turbine manufacturers. We are creating a team – Matric Manufacturing, Intergrid, and Windurance- to cover all aspects of commercial product supply including engineering, manufacturing, production testing, marketing and field support.

**Anticipated outcomes / deliverables:**

The work will start with a "Design for Manufacture" review followed by documentation, supply chain and procedure development. Board-level, functional test and burn-in capabilities will be created. The main outcome is to bring the Intergrid inverter to full manufacturing readiness with the capability of producing more than 1000 units per year, and to support the needs of multiple distributed wind turbine manufacturers.

**Collaboration interests:**

1. Distributed wind turbine manufacturers
2. Battery energy storage system manufacturers and integrators
3. Electric vehicle charging infrastructure including demand control systems
4. Any application needing high-power single-phase inverters.

### 3 Wind Innovations for Rural Economic Development (WIRED)

Enabling wind energy technology as a DER to be more valuable—in terms of generating reliable low-cost power, providing grid services, and resilience—for rural electric utilities and communities is a large opportunity. Rural electric cooperatives alone own nearly \$200 billion in assets, invest more than \$10 billion annually in local economies, and power more than 50% of the U.S. landmass. NREL analysis, [Assessing the Future of Distributed Wind](#), suggests the potential for distributed wind capacity additions (>10 GW) is especially high on rural distribution grids, with the potential for hundreds of thousands of turbines installed at farms, small businesses, and residences in rural areas.

The WIRED topic under WETO’s 2019 Funding Opportunity Announcement aims to help unlock this potential opportunity by (1) developing wind technology solutions in combination with other DERs to enhance grid services for rural electric customers, rural distribution utilities, and rural generation and transmission utilities, and (2) by reducing balance of system costs— which can total more than 50% of the total cost of a distributed wind project— through mitigation of technical market barriers, system standardization, and technical assistance. The following 4 projects were awarded funding under the WIRED topic.

#### 3.1 Iowa State University: Optimal Operation and Impact Assessment of Distributed Wind for Improving Efficiency and Resilience of Rural Electricity Systems

**Project PI:** Zhaoyu Wang, [wzy@iastate.edu](mailto:wzy@iastate.edu), (515) 294-6305

**Project Team:** Iowa State University (ISU), Wind Utility Consulting, Algona Municipal Utilities, Central Iowa Power Cooperative (CIPCO), Corn Belt Power Cooperative, Iowa Lake Electric Cooperative, Greenfield Municipal Utilities, and American Public Power Association (APPA)

##### **Short Project Description:**

The project will design optimization models and control algorithms that enable rural utilities to leverage distributed wind in coordination with other distributed energy resources (DERs) to shave peak demand and provide emergency power. The team will also develop an ultrafast technique to evaluate impacts of distributed wind and optimize battery storage systems as a mitigation strategy for potential issues. The project outcomes will be backed by mathematical analysis and large-scale numerical simulations. Furthermore, our utility partners will demonstrate developed algorithms in a real distributed wind farm.

##### **Anticipated outcomes / deliverables:**

This project will address challenges raised by rural utilities and provide real-time operation support for rural grids with distributed wind. It will benefit rural utilities and distributed wind industry by significantly enhancing system reliability and resilience through distributed wind. Furthermore, the project enables major operational cost savings, emission reduction, and optimal utility investment in battery storage technology for mitigating operational vulnerabilities.

##### **Collaboration interests:**

Distributed wind farm developers and owners, and rural utilities that have current or planned distributed wind on their system.

### 3.2 Electric Power Research Institute (EPRI): Wind Intelligently Integrated into Rural Energy Systems (WIRES)

**Project PI:** Brandon Fitchett, bfitchett@epri.com

**Project Team:** Electric Power Research Institute (EPRI), GE Global Research, NRECA

**Short Project Description:**

This project will seek to identify and model novel operational strategies for distributed wind assets and complementary technologies (such as battery storage or load management) that will allow wind penetration levels to increase to the greatest extent possible on rural distribution systems while maintaining expected power quality and aiming to reduce electricity cost. In order to ensure widespread applicability of this work, a number of differing grid systems (e.g., islanded, singular connection to bulk transmission), geographies, and demand profiles will be modeled to determine necessary wind operation and resource mix necessary to maximize wind generation on the grid for the given conditions.

**Anticipated outcomes / deliverables:**

1. Determine wind power hosting capacities of a diverse set of distribution systems
2. Validate tools used for these calculations and update tool capabilities to include validated advanced wind turbine controls for automated or fast-response grid services
3. Including new modes of wind turbine operation, such as with 'headroom', determine whether these operational modes may be more cost effective than battery storage alone for providing grid services
4. Statistical evaluations for periods of time expected to have zero wind energy available
5. Provide guidelines and tools for future analysis of high amounts of wind energy or wind+storage on other small grid or distribution systems.

**Collaboration interests:**

1. Distribution modeling of utility-scale wind turbines
2. Wind turbine or wind farm controllers for grid services
3. Wind and battery hybrid system optimization for value of grid services

### 3.3 National Rural Electric Cooperative Association (NRECA): Rural Area Distributed Wind Integration Network Development (RADWIND)

**Project PI:** Venkat Banunarayanan, Venkat.Banunarayanan@nreca.coop, 703-850-7831

**Project Team:** NRECA Research, Pacific Northwest National Laboratory, Hoss Consulting, Mana Group

**Short Project Description:**

The RADWIND project seeks to understand, address, and reduce the technical risks and market barriers to distributed wind (DW) adoption by electric cooperatives and other rural utilities through the identification of solutions, development of shareable resources, and demonstration of technology by and with rural communities. This includes both DW as a standalone resource, and DW deployed in conjunction with other DER.

**Anticipated outcomes / deliverables:**

This project will deliver a variety of resources and deliverables, including case studies, DW use/value/business case documents, technical and financial resources, partnership models, and an open database of distributed wind projects in Rural America.

**Collaboration interests:**

1. Electric co-ops/rural utilities with experience in DW and/or other DER deployment;
2. Stakeholders in the DW and larger DER/renewable space;
3. Financial institutions that lend to co-ops and other renewable utilities

### 3.4 Bergey Windpower: Business Model for Rural Cooperative Distributed Wind Microgrids

**Project PI:** Mike Bergey, mbergey@bergey.com, 405-364-4212

**Project Team:** Bergey Windpower Co., Oklahoma Electric Cooperative, Intergrid, Intertek, DNV GL, Idaho National Laboratory, New Context, Visual BI, Juhl Energy

**Short Project Description:**

The project team will work with Oklahoma Electric Cooperative to refine the "DER-Sales" business model, answer the implementation questions and create planning templates that can be used by other rural electric cooperatives to deploy distributed wind microgrid projects.

**Anticipated outcomes / deliverables:**

1. A detailed, vetted and replicable business model for rural electric cooperative sales of small wind microgrids for homes, farms and small businesses.
2. A demonstration of the technical and operational viability of a standardized small wind microgrid system and its ability to integrate into a virtual power plant,
3. Detailed design for a pilot project,
4. Opportunities for larger distributed wind applications on rural electric cooperatives.

**Collaboration interests:** None at this time.

## 4 National Laboratory Based Research Activities

In 2018 WETO solicited proposals for multi-year projects from the national laboratories under the DW program for projects beginning in 2019. Proposals were asked to address near term technical challenges associated reducing LCOE, performance risk, and market barriers. The following projects were selected using an external merit review process.

### 4.1 Sandia National Lab: Defense and Disaster Deployable Turbine (D3T)

**Project PI:**

Brian Naughton, bnaught@sandia.gov, 626-233-3108

**Project Team:**

Sandia National Laboratories, Idaho National Laboratory, National Renewable Energy Laboratory

**Short Project Description:**

The Defense and Disaster Deployable Turbine (D3T) project is evaluating the market potential for rapidly deployable wind energy technologies, developing wind turbine design requirements for operational applications, and assessing commercially available wind technologies against operational design requirements to help identify technology gaps and research and development opportunities.

**Anticipated outcomes / deliverables:**

1. Market opportunity assessment for deployable wind turbines in defense and disaster response applications (complete)
2. Modeling and simulation analysis to identify deployable wind technologies and scenarios that could provide maximum value in terms of application specific metrics (e.g. avoided fuel)
3. Design guidelines to facilitate technology development that

**Collaboration interests:**

1. Wind technology developers with interest in the defense and disaster response application space
2. System integrator's that can provide integrated mobile energy solutions
3. Test site owners where prototype systems could be demonstrated

### 4.2 National Renewable Energy Laboratory: Tools Assessing Performance (TAP)

**Project PI:** Heidi Tennesand, heidi.tennesand@nrel.gov, 720-390-8784

**Project Team:** Argonne National Laboratory, Los Alamos National Laboratory, National Renewable Energy Laboratory, Pacific Northwest National Laboratory.

**Short Project Description:**

The TAP project endeavors to produce fast, accurate, and inexpensive wind resource estimates for the distributed wind industry without having to rely on the deployment of instrumentation at project sites.

**Anticipated outcomes / deliverables:**

1. 20-year time series wind resource dataset at distributed wind heights.
2. Analytical tool which evaluates the wind resource at any point in the U.S.
3. Characterization of the uncertainty in the wind resource estimate.

**Collaboration interests:**

1. Turbine manufacturers who are looking to produce more accurate wind resource estimates.
2. Partners who can help the team secure validation sites where we can deploy multiple LiDAR.

#### 4.3 National Renewable Energy Laboratory: Distributed Wind Energy Modeling and Analysis

**Project PI:** Eric Lantz, Eric.Lantz@nrel.gov, 303-384-7418

**Project Team:** National Renewable Energy Laboratory; Pacific Northwest National Laboratory

**Short Project Description:**

This project supports the execution of market and technology assessments, to inform basic science R&D strategy in distributed wind energy while providing important market data, insights and tools to the distributed wind industry. More specifically, this effort provides an improved understanding of the market conditions that may foster or constrain distributed wind technology development while helping to inform potential pathways for realizing lower installed costs and lower cost of energy.

**Anticipated outcomes / deliverables:**

The project typically generates market and technology intelligence as captured through publications and public presentations. It also develops open source tools and data to inform the public and private sectors regarding market opportunities and potential for distributed wind energy deployment.

**Collaboration interests:**

1. Characterization of the future technology and R&D needs for distributed wind energy systems
2. Characterization of the standardized customers/deployment opportunities/market structures that provide the best near-term opportunity for distributed wind energy deployment
3. Exploration of standardized turnkey technology solutions as well as the potential for modularity in order to reduce deployment related transaction costs and support cost savings in equipment, installation and O&M

#### 4.4 National Renewable Energy Laboratory: Microgrids, Infrastructure Resilience and Advanced Controls Launchpad (MIRACL)

This collaborative research project—which includes DOE’s National Renewable Energy Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, and Idaho National Laboratory—uses a high-speed data link to leverage nearly a billion dollars’ worth of research capabilities and DER infrastructure across the four laboratories. This enables research, development, and industry validation

of DER components and hybrid energy systems across multiple scales and configurations in geographically diverse operating conditions. The MIRACL project is organized under the following three R&D priorities, and project profiles broken out accordingly.

#### 4.4.1 Pacific Northwest National Laboratory: Improving Distributed Wind Valuation and Representation in Tools

**Project PI:** Alice Orrell, [alice.orrell@pnnl.gov](mailto:alice.orrell@pnnl.gov), 509-372-4632

**Project Team:** Pacific Northwest National Laboratory

**Short Project Description:**

Research at PNNL under the Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) will improve the representation and valuation of distributed wind in distribution planning tools, methods, and models by developing a valuation framework; evaluating, modernizing, and validating existing tools; and, exploring use cases through key infrastructure investments. Use cases could include wind plus solar and/or storage, wind as part of microgrids, and wind in transactive energy environments. Data from physical turbines at the national laboratories will be used to characterize wind performance in each of these use cases and will support modernizing and validating modeling tools and development of a comprehensive valuation framework.

**Anticipated outcomes / deliverables:**

- Identifying and characterizing grid impacts from the integration of distributed wind
- Identifying and characterizing grid services that distributed wind can provide
- Understanding distributed wind behavior characteristics under varying grid conditions
- Understanding resilience improvements from distributed wind in microgrids
- A valuation framework for distributed wind with worked examples

**Collaboration interests:**

- Wind turbine manufacturers with interest in developing new or additional case studies for valuation and modeling.
- Power system operators with high-wind contribution systems interested in additional, or improved, markets for distributed wind grid services.
- Modeling and simulation tool developers, and end-users, interested in supporting the improvement of distributed wind representation in these tools.
- Stakeholders interested in new valuation frameworks for distributed wind, considering value components that are temporal or geographically based, including resilience and economic benefits.
- Utilities or communities interested in understanding and/or communicating the value of distributed wind in their jurisdiction.

#### 4.4.2 National Renewable Energy Laboratory: Advanced Controls for Distributed Wind

**Project PI:** Jim Reilly, [james.reilly@nrel.gov](mailto:james.reilly@nrel.gov), 646-670-8965; Brian Naughton, [bnaught@sandia.gov](mailto:bnaught@sandia.gov), 626-233-3108

**Project Team:** National Renewable Energy Laboratory and Sandia National Laboratories

**Short Project Description:**

The Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad (MIRACL) controls team is working to expand the benefits from distributed wind energy assets beyond solely providing low-cost power directly to consumers. To make these turbines operate more effectively, there is a need for more advanced ways to control them—allowing power companies, businesses, and energy consumers to take advantage of some of the unique technical characteristics of wind energy. Teams from the National Renewable Energy Laboratory (NREL) and Sandia National Laboratories (SNL) plan to use their advanced power system simulation laboratories and wind turbine test facilities to research, develop, and demonstrate advanced control functions to be employed by distributed wind systems of the future. The advanced controls developed through MIRACL will optimize existing wind turbine hardware to reduce downtime and increase overall power system stability in lieu of, or in support of, conventional generation sources.

**Anticipated outcomes / deliverables:**

- Publicly available technical reports that summarize flexible control functions and capabilities of typical distributed wind turbine controllers to improve grid support over a defined set of distributed wind turbine use cases, including hybrid systems.
- A report examining the impacts of new requirements in IEEE 1547-2018 on distributed wind turbines.
- A better understanding of the different control and hardware configurations required to support transitions between grid-connected and grid-isolated microgrids, expanding beyond just wind systems.
- Case studies of high-wind-contribution isolated and grid connected distribution systems with integrated storage including initial simulations and field testing, documenting the actual costs, benefits, and complexities associated with these applications.

**Collaboration interests:**

- Wind turbine manufacturers with interest in developing new or additional case studies for advanced control methods and technologies
- Distribution power system operators with high-contributions of wind and interest in wind participating in grid stability services and operations
- Controls developers interested in integrating multiple generation sources and further advancing wind participation in power system operations, such as Distributed Energy Resource Management Systems (DERMS).

#### 4.4.3 Idaho National Laboratory: Distributed Wind Resilience and Cyber Security

**Project PI:** Jake Gentle, Jake.Gentle@inl.gov, 208-526-1753

**Project Team:** Idaho National Laboratory

**Short Project Description:**

The Distributed Wind (DW) community must improve its resilience and cybersecurity posture as it seeks to expand from being a local electricity provider, to a source of aggregate generation on the electrical grid. This can be accomplished by utilizing tools and methodologies that tackle DW vulnerabilities and advance the benefits that DW can offer the larger energy sector. INL plans to approach this through four main work packages: • Quantifying and Improving System Resilience Provided by Distributed Wind • Analyzing and Mitigating Distributed Wind Cyber Threats and System Health • Development of and

Access to the MIRACL Data Hub • Demonstrate Quick Recovery, Deploy-ability, and Hardening from Natural Disasters.

**Anticipated outcomes / deliverables:**

- An easy-to-use toolset will be built to consider the probability and consequence of disruptions in power systems and quantify the ability of power systems to adapt to a natural disaster or cyber-attack
- Cyber hygiene recommendations will be defined for DW Use Cases and associated roles. Cyber-physical anomaly detection methods will be developed and applied to DW, concluding with mitigation strategies to minimize cyber and/or physical event impacts on DW infrastructure and its interdependencies
- Central location for MIRACL members to access information repository (Data Hub) for real analysis and experimentation
- Provide hardening recommendations for DW (permanent and deployable assets) from natural disasters

**Collaboration interests:**

- Wind turbine manufacturers, wind system operators, microgrid system operators, and customers with interest in participating in the development and/or adoption of new cyber security approaches.
- Wind turbine manufacturers, wind system operators, microgrid system operators, and customers with interest in participating in the development and/or adoption of new resilience valuation metrics and hardening from natural disasters

## 5 Complementary Programs – Small Business Innovation Research

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are highly competitive programs that encourage domestic small businesses to engage in Research and Development (R&D) with the potential for commercialization. SBIR and STTR enable small businesses to explore their technological potential and provide the incentive to profit from its commercialization. By including qualified small businesses in the nation's R&D arena, high-tech innovation is stimulated, and the United States gains entrepreneurial spirit as it meets its specific research and development needs.

Under the 2020 SBIR call for proposals, WETO invited proposals for technology innovations that address technology gaps for distributed, land-based, and offshore wind with the potential to enable wind power to generate electricity in all 50 states cost competitively with other sources of generation. The following was a project was selected for funding.

### 5.1 Pecos Wind Power: Tilt-Up Tower and Installation System to Reduce the Cost of Distributed Wind Turbines

**Project PI:** Josh Groleau, josh@pecoswindpower.com, 207-745-2231

**Project Team:** Pecos Wind Power, University of Massachusetts-Amherst, Renewable Concepts Inc.

#### Short Project Description:

This SBIR Phase I effort is to research and develop a novel tilt-up tower and installation system for small-scale distributed wind turbines – an innovation capable of achieving a 12% reduction, approximately \$923/kilowatt (kW), in the installed cost of 21-100 kW wind turbines. The technology targets two of the most costly aspects of a distributed wind turbine project: tower systems and balance of station (e.g. transportation, assembly, and installation). The technical approach introduces several untested concepts to the small wind industry, including a reusable tilt-up fixture, telescoping tower sections, spiral welded pipe, and tower standardization across turbine makes/models.

#### Anticipated outcomes / deliverables:

1. We are targeting a 12% reduction in the installed cost of 21-100 kW distributed wind turbines.
2. We aim to domestically manufacture this tower system.
3. We aim to standardize this tower system for 85-100 kW turbines and license it for 21-85 kW turbines.

#### Collaboration interests:

We would like to increase the scope of this project by researching lower cost foundation concepts for 21-100 kW wind turbines. We are looking to collaborate with wind turbine project developers, wind turbine installers, wind turbine OEMs, academic researchers, civil engineering firms, concrete companies, and anyone who has in-depth knowledge of wind turbine foundation costs and foundation design theory.

U.S. DEPARTMENT OF  
**ENERGY**

*Office of*  
**ENERGY EFFICIENCY &  
RENEWABLE ENERGY**

For more information, visit:  
[energy.gov/eere/wind](https://energy.gov/eere/wind)

PNNL 30894 • February 2021