July 2023

RADWIND Project
Final Technical Report

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NRECA
America's Electric Cooperatives

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RADWIND Project Final Technical Report

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List of Acronyms

ARC—all-requirements contract
CIP—Competitiveness Improvement Project
DER—distributed energy resource(s)
DG—distributed generation
DOE—Department of Energy
EERE—Office of Energy Efficiency and Renewable Energy
G&T—generation and transmission cooperative
INL—Idaho National Laboratory
ISG—Industry Stakeholder Group
LCOE—levelized cost of energy
MSG—Member Stakeholder Group
NIMBY—not in my back yard
NRECA—National Rural Electric Cooperative Association
OCED—Office of Clean Energy Demonstrations
OEM—original equipment manufacturer
NREL—National Renewable Energy Laboratory
PAG—Project Advisory Group
PNNL—Pacific Northwest National Laboratory
PT—Project Team
RADWIND—Rural Area Distributed Wind Integration Network Development
REAP—Rural Energy for America Program
RFP—request for proposal
SOPO—statement of project objectives
WETO—Wind Energy Technologies Office
WIRED—Wind Innovations for Rural Economic Development

Executive Summary

The Rural Area Distributed Wind Integration Network Development (RADWIND) Project (January 2020-April 2023) was undertaken by NRECA Research, a not-for-profit subsidiary of NRECA focused on underwritten research, with the support of DOE. The project was part of the Wind Energy Technologies Office's (WETO's) Wind Integration for Rural Economic Development (WIRED) program, which was developed out of an October 2018 workshop in which NRECA participated in.

RADWIND's end of project goal was "to raise awareness of distributed wind as a solution for the energy, resiliency, and economic development needs of electric cooperatives, and to provide resources and information that reduce barriers and lower costs for co-ops seeking to deploy distributed wind. Through this project, NRECA Research seeks to establish a national distributed wind presence for and by NRECA's members that delivers these benefits and plans to communicate NRECA's members that properly deployed distributed wind can be a bankable technology option for rural America."

Key deliverables, tools, and outcomes of the project are:

- Dedicated RADWIND web page on NRECA's member-facing cooperative.com website for consolidated dissemination of resources; this site will persist as a distributed wind resource hub although project funding has concluded.
- A national database that utilities, developers, and other stakeholders can use to locate distributed wind projects based on various criteria (geography, turbine type, other hybrid technologies, electric cooperative or other utility involvement, etc.).
- Four major reports on the use case, value case, business case, and financing of distributed wind.
- Thirteen case studies that documented organizational, technical, community, and financial aspects of distributed wind projects at electric cooperatives and other rural utilities.
- A high-level overview report on distributed wind development practices for electric cooperatives and other rural utilities that includes information on how distributed wind projects progress from concept to reality; the tools, methods, and resources developers utilize to screen and manage projects; how stakeholders are engaged; and information about required project approvals.
- A Distributed Wind Toolkit that distills the learnings of the RADWIND reports and other resources into five educational "modules" for cooperatives.
- Twenty-one NRECA member cooperatives and rural utilities and 17 industry stakeholders of various types participated in the project.

Key findings of the project are:

- Distributed wind is cost-effective and well-received by the rural utilities that deploy it. However, the strong promotion of solar for distributed applications coupled with negative experiences with distributed wind turbines decades ago continue to deter many rural communities from considering distributed wind.

- Increased outreach and education on modern distributed wind turbines and current federal incentives coupled with nationwide availability of developers that understand rural utility environments is essential for rural America to take full advantage of the distributed wind opportunity.
- The shift of many major renewable advocacy groups away from advocating for a single technology could help distributed wind, especially where there are opportunities to include wind in hybrid projects utilizing multiple complimentary technologies (for example – wind plus solar and batteries).
- One proven major value stream that has been identified in case studies and project research is the ability of distributed wind to reduce the need for expensive wholesale power (which can include energy, capacity, and transmission charges) during times of peak demand, and screening tools to support this value stream would be helpful.
- A greater degree of standardization might make distributed wind projects more attractive for electric cooperatives, including G&T cooperatives that might choose to deploy several projects across their territory.
- There are opportunities for integrating distributed wind or distributed wind hybrids with other behind the meter DER on the same distribution grid – such as using grid-enabled water heaters as a virtual battery to store excess wind energy. There also might be opportunities for pairing on-site distributed wind with EV charging, where wind's production overnight offers it an advantage over solar generation.
- There is a lack of easy-to-use/access screening tools (similar to PVWatts for solar) for distributed wind, especially for small- and medium-scale turbines. Like PVWatts, this tool would need to be accessible to homeowners and small building owners who are interested in distributed renewable generation and might be open to wind as a technology option.
- There are opportunities for business models like "community wind" where a portion of the output could be purchased and assigned to individual consumer-members in lieu of a wind-turbine or solar panels at their home or businesses.

Introduction

The National Rural Electric Cooperative Association (NRECA) is the national service organization for nearly 900 electric cooperatives and other rural utilities serving 42 million Americans in 48 states.

The RADWIND project was undertaken by NRECA Research, a not-for-profit subsidiary of NRECA focused on underwritten research, with the support of DOE. The project was part of WETO's Wind Integration for Rural Economic Development (WIRED) program, which was developed out of an October 2018 workshop in which NRECA participated in.

The project was awarded in January 2020, and after final negotiations major project work began in August 2020. The RADWIND project concluded on April 30, 2023.

In addition to NRECA Research, the RADWIND Project Team (PT) included three partner organizations with expertise on various aspects of distributed wind:

- **Hoss Consulting** (Hoss): A technical and management consulting group focused on renewable energy, telecommunications, and critical power industries. Served as the technical lead on the project.
- **Mana Group, LLC** (Mana): Provides business strategy, consulting, and commercial advisory services for renewable energy, climate change, and corporate sustainability. Served as the industry outreach and finance lead on the project.
- **Pacific Northwest National Laboratory** (PNNL): One of the United States Department of Energy national laboratories, managed by the Department of Energy's Office of Science. Served as the data and analysis lead on the project.

Tasks and Resources

As laid out in the Statement of Project Objectives (SOPO), RADWIND's end of project goal was:

> To raise awareness of distributed wind as a solution for the energy, resiliency, and economic development needs of electric cooperatives, and to provide resources and information that reduce barriers and lower costs for co-ops seeking to deploy distributed wind. Through this project, NRECA Research seeks to establish a national distributed wind presence for and by NRECA's members that delivers these benefits and plans to communicate NRECA's members that properly deployed distributed wind can be a bankable technology option for rural America.

To achieve this goal, the major work of the project was split into four tasks,[1] each of which includes several subtasks with associated resource deliverables and milestones.

Task 1: Serve as the Trusted Technical Channel to Electric Cooperatives

Task 1 focused on outreach to NRECA's electric cooperative and other rural utility members, as well as distributed wind industry stakeholders.

An early deliverable for this was a project landing page on cooperative.com, NRECA's member-facing website for employees and directors of America's Electric Cooperatives. Information on the project and all resources developed under RADWIND are shared publicly on this landing page, accessible using the simplified URL www.cooperative.com/radwind.[2] This page serves as a central repository for distributed wind content and has been frequently updated during the project. NRECA plans to maintain this page as a home for distributed wind resources beyond the life of the project, adding new relevant materials as appropriate. All resources mentioned in this section can be found on the landing page, and the Appendix also includes full citations and direct links.

Images 1 & 2: The RADWIND Landing Page

[1] Task 5 covered Project Management and Reporting.
[2] The full web address is https://www.cooperative.com/programs-services/bts/radwind/Pages/default.aspx.

Task 1 also called for the development of a Project Advisory Group (PAG) to provide insight and feedback to the PT. The PAG consisted of two groups, a Member Stakeholder Group (MSG) and an Industry Stakeholder Group (ISG).

Seven NRECA members—five distribution cooperatives and two generation and transmission (G&T) cooperatives—formally participated in the MSG, with multiple staff participating from some organizations. Eight virtual MSG meetings were held (including two jointly with the ISG) during the project to discuss project direction and deliverables in development and solicit input and feedback. The Project Team distributed draft materials by e-mail for review by the MSG and also held several informal "listening session" calls with individual members to dive deeper into specific issues. The MSG did not reach its goal of 12 participants, so members of NRECA's existing Member Advisory Group on Distributed Energy Resource (DER) technologies were also asked to review some project resources, including case studies and technical advisories. In total, staff from 21 NRECA members plus NRECA staff not on the project team participated in some aspect of the project, including advisory and review activities, in person or virtual presentations, or by being featured in a deployment or finance case study.

Table 1: RADWIND Member Stakeholder Group and Other Participants

Organization	Type	HQ State	Member Stakeholder Group	Resource Review	Case Study Participant	Presenter
Adams Electric Cooperative	Distribution Co-op	IL			X	X
Basin Electric Power Cooperative	Distribution Co-op	ND			X	X
Central REC	Distribution Co-op	OK	X			
Claverack Rural Electric Cooperative, Inc.	Distribution Co-op	PA		X		
Corn Belt Power Cooperative	G&T Co-op	IA			X	
Cuming County PPD	Distribution PPD	NE			X	
Fox Islands Electric Co-op	Distribution Co-op	ME			X	
Homer Electric Association., Inc.	Distribution Co-op	AK			X	
Iowa Lakes Electric Cooperative	Distribution Co-op	IA	X		X	X
Kotzebue Electric Association, Inc.	Distribution Co-op	AK			X	
Lake Region Electric Cooperative	Distribution Co-op	MN	X		X	X
National Rural Electric Cooperative Assn.	Trade Association	VA		X		X
New Hampshire Electric Co-op	Distribution Co-op	NH		X		
Oklahoma Electric Cooperative	Distribution Co-op	OK			X	
Rural Electric Convenience Cooperative	Distribution Co-op	IL			X	
San Isabel Electric Assn., Inc.	Distribution Co-op	CO	X		X	X
Sunflower Electric Power Corp.	G&T Co-op	KS	X			
Tri-State G&T Assn., Inc.	G&T Co-op	CO	X			
Umatilla Electric Cooperative	Distribution Co-op	OR		X		
United Cooperative Services, Inc.	Distribution Co-op	TX	X			
Wright-Hennepin Cooperative Electric Assn.	Distribution Co-op	MN		X		
Y-W Electric Association, Inc.	Distribution Co-op	CO			X	

NRECA Research used a variety of avenues to publicize RADWIND and its resources to NRECA Members, staff, and Board of Directors:

- NRECA's twice-monthly Business and Technology Update newsletter (online)

- Professional Communities on cooperative.com that target communications to members with interest in distributed wind or DER more generally (online)
- Sessions or pre-conference sessions at NRECA's TechAdvantage in 2020, 2022, and 2023 (in person)
- Presentations to NRECA staff, NRECA's Board of Directors, and the Strategic Advisory Committee (a group of senior co-op leaders that advises NRECA on research priorities) (in person)
- NRECA's "Along These Lines" podcast episode (June 2021) featuring RADWIND (online
- Articles in *RE Magazine*, NRECA's flagship publication for staff and directors of electric cooperatives (print and online)
- Webinars focused on distributed wind, or where distributed wind was covered as part of a wider discussion on wind resources (online).

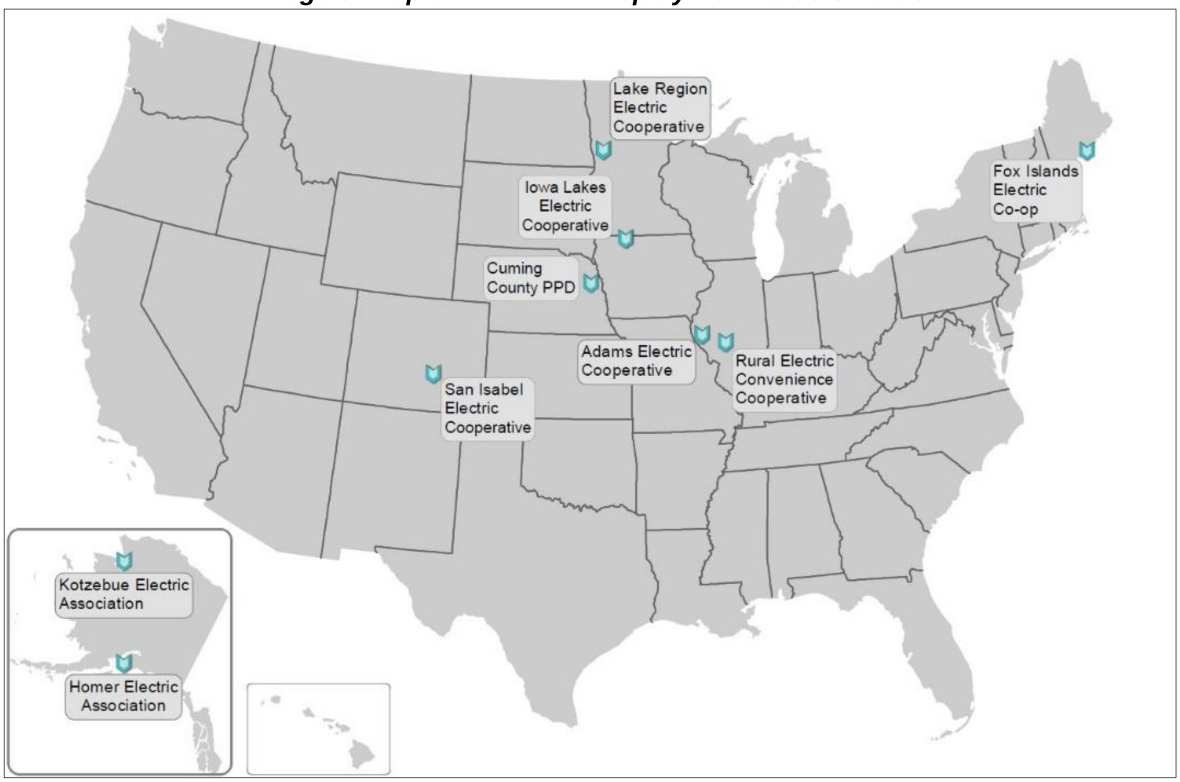
Seventeen industry stakeholders of various types participated in the ISG or in other aspects of the project. Five virtual ISG meetings were held (including two joint calls with the MSG) to discuss project deliverables in development and solicit input and feedback, as well as direct consultation with participants on specific topics as needed. Some of these organizations also contributed directly to project resources. As part of industry outreach, NRECA research also participated in the Distributed Wind Energy Association's annual conferences in 2020, 2022, and 2023 to discuss RADWIND and electric cooperative involvement in the distributed wind space.

Table 2: RADWIND Industry Stakeholder Group and Other Participants

Organization	Type	Industry Stakeholder Group	Resource Contributor
ArcVera Renewables	Resource Modeling	X	X
All Energy Management	Installer	X	
Bergey Windpower Co.	OEM	X	X
BlueStem Energy Solutions	Developer	X	X
Buffalo Renewables, Inc.	Developer		X
Digital Engineering Ltd.	Resource Modeling	X	
Eocycle	OEM	X	
EWT	OEM	X	
Foundation Windpower	Developer	X	X
Juhl Energy Inc.	Developer	X	
National Renewable Energy Laboratory	Government Lab	X	X
Nixon Peabody, LLC	Legal Consulting	X	
Pecos Wind Power	OEM	X	
Seminole Financial	Finance	X	
The Stella Group, LTD	Tech Policy	X	
UL Solutions/UL Homer	Standards/Hybrid Modeling	X	X
Xendee	Microgrid/Hybrid Modeling		X

Another major component of Task 1 was the development of nine deployment case studies. These document the varied existing deployments of distributed wind by NRECA members in several states and regions. These case studies show the variety of ways that co-ops have successfully deployed wind as a distributed energy resource, including owned and contracted projects at various scales, deployment as part of a hybrid with other DER, and as part of a net metering program. They provide lessons learned which can help other rural utilities seeking to utilize distributed wind. Each case study also provides contact information for staff at the featured organizations who can be contacted for more peer-to-peer information, as well as a point of contact at NRECA. Selection of projects was based off of NRECA's database of distributed wind projects, which was reviewed and updated as part of this project in preparation for creation of a public database with PNNL discussed below under Task 4.

Image 3: Map of RADWIND Deployment Case Studies



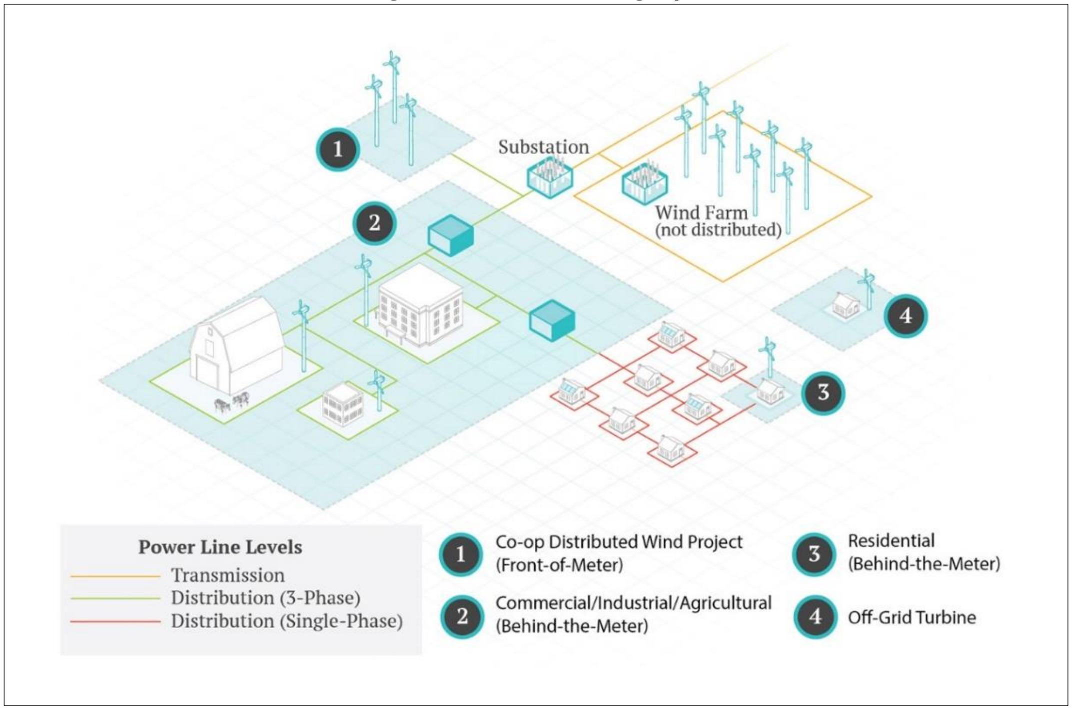
A final major deliverable of Task 1 were surveys of NRECA's distribution members regarding their awareness, experience, and interest in wind technologies as a distributed generation (DG) resource, either on its own or in conjunction with other DER technologies. Two surveys were conducted as part of RADWIND, in February 2021 and 2023, with summary reports posted on the landing page. In particular, the first survey was used by the PT to help validate and guide resource development. The second survey requested additional feedback for future research priorities or resource needs in this space. Respondents to both surveys were also asked if they were interested in more information on distributed wind, and those who answered yes were added to a Distributed Wind Professional Community on cooperative.com.

Task 2: Define Use Case, Value Case, and Business Case for Distributed Wind

Task 2 encompassed the development of four major project reports focused on the use case, value case, business case, and financing of distributed wind resources. These reports represent a significant foundation of information and knowledge about distributed wind for NRECA and its members.

The development of the first of these reports, *Use Cases for Distributed Wind in Rural Electric Cooperative Service Areas*, was led by PNNL and established a framework for defining distributed wind across three major use cases (front-of-meter, behind-the-meter, and off-grid) as well as how different scales of turbines and hybridization with other DER technologies fit into these use cases. These use cases set up a framework that would be used across the rest of the project's resources in dealing with various ways that wind can be used as a DER. The infographic below shows these three use cases, with distinction between behind-the-meter deployments at businesses vs. residential deployments.

Image 4: Use Case Infographic



The second major report developed under Task 2 was *Value Case for Distributed Wind in Rural Electric Cooperative Service Areas*, with primary authorship by PNNL. This report highlighted a variety of monetary and non-monetary value streams that distributed wind can provide rural utilities, as well as some potential value streams (e.g., ancillary services) that distributed wind could provide given market structures that would compensate them. This report was revised in December 2022 to note changes in federal tax credits applicable to distributed wind after the passage of the Inflation Reduction Act.

The third major Task 2 report was *Financing Distributed Wind Projects in Rural Electric Cooperative Service Areas*, with writing and research led jointly by Mana and Hoss. This report looks at various types of financing, incentives, and business models that can be used by electric cooperatives and other rural utilities to deploy distributed wind projects, or to support their consumer-members in doing so. This content was originally going to be developed as standalone case studies, but the PT decided instead to consolidate this information into report form.

The final major report developed under Task 2, *Business Case for Distributed Wind in Rural Electric Cooperative Service Areas*, led by Hoss with portions from Mana, PNNL, and NRECA Research. Building on the three prior reports, this report sought to identify and address market barriers to distributed wind adoption by laying out the business case for distributed wind across the three use cases identified in the first report. The report addresses how these use cases can involve wind turbine technologies of various scales, as well as hybridization with other complimentary technologies such as solar PV and battery energy storage.

In addition to major reports, a series of finance case studies was also produced focusing on financing and business models that can be applied to distributed wind. Unlike the deployment case studies, which mostly focused on larger front-of-meter deployments, these focused mostly on potential or actual distributed wind resources using smaller turbines located behind-the-meter at homes and businesses. Four of these case studies were produced focusing on the potential for on-bill financing programs used for other DER to be applied to distributed wind, a long-lived small residential wind turbine, a commercial deployment utilizing three larger turbines at a commercial agricultural businesses, and a final case study exploring ways that co-ops and developers can best work together on behind-the-meter projects drawing lessons from some of the projects discussed in earlier deployment and finance case studies.

Task 3: "Right Sized" Member-Driven Technology Solutions

The primary resource developed under Task 3 was the *Distributed Wind Project Development Practices in Rural Electric Cooperative Service Areas (Development Practices Report)*, which was primarily written by Hoss but with contributions from external subject matter experts. This report serves as a high-level overview for electric cooperatives and other rural utilities of how distributed wind projects progress from concept to reality; the types of tools, methods, and resources developers utilize to screen and manage projects as they progress; how stakeholders are engaged; what approvals may be required for a project to progress; and how and when those approvals are secured. This report also details the costs of developing, installing, and operating a distributed wind asset and the cash flows that result when the asset is put into service. Image 5 below, the report's Table of Contents, outlines the topics covered by this report, which align with various subtasks of Task 3 and parts of Task 4 from the project SOPO.

Image 5: Development Practices Report Table of Contents

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Three video resources featuring subject matter experts were also posted on the RADWIND web page as part of Task 3:

- A recording of a RADWIND webinar on "Modeling Tools for Distributed Wind Hybrid System Sizing, Integration & Optimization" that introduces the fundamentals of hybrid system sizing and integration from an optimization perspective, with presentations from NRECA, UL Homer, XENDEE, and National Renewable Energy Laboratory (NREL).
- Two videos featuring subject matter experts from ArcVera Renewables and Digital Engineering who discuss digital modeling for wind resource assessment, especially useful for smaller distributed wind projects as a supplement or replacement for on-site testing equipment.

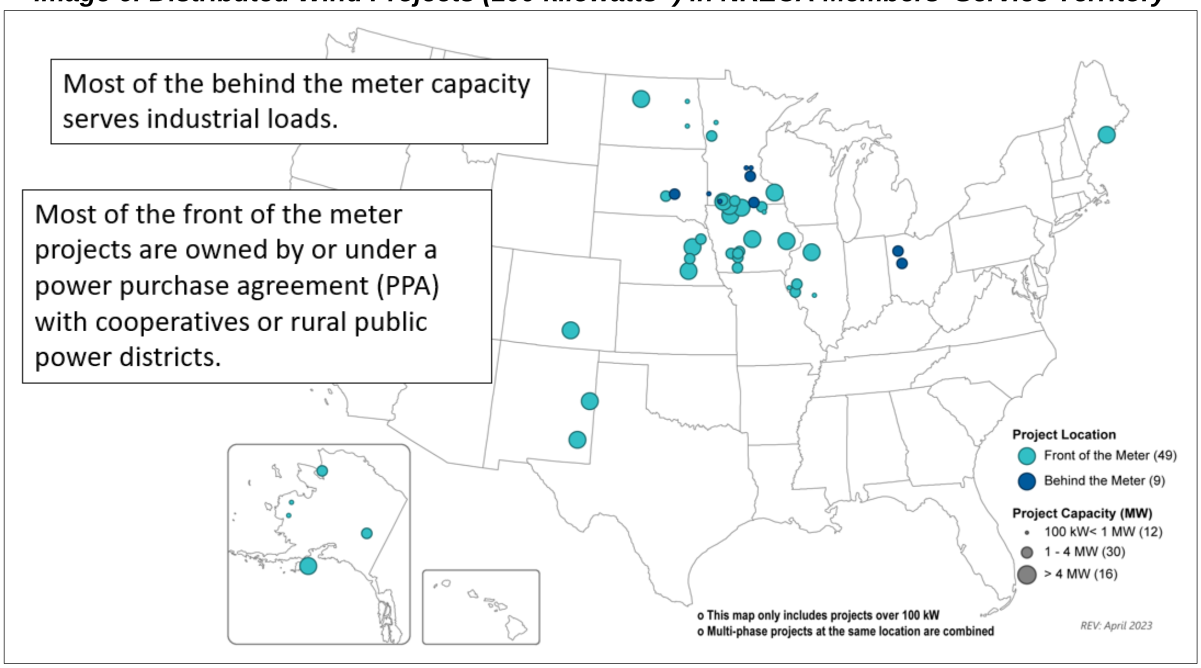
In general, the goal of these videos is to help co-op staff understand the capabilities of these types of models, their strengths and weakness, and how they might be used by developers so that a co-op can perform due diligence for proposed distributed wind or distributed wind hybrid projects even if they are utilizing these tools directly.

NRECA Research also developed four additional technical advisories covering topics of interest. The first of these was a summary of NREL's January 2022 report, *Wind and Solar Hybrid Power Plants for Energy Resilience*. The advisory emphasized the important concept of wind/solar complementarity across much of the United States as a method of increasing the value of hybrid projects combining these technologies. A series of three advisories focused on small- and medium-scale wind turbines that are most commonly deployed behind-the-meter rather than directly by electric cooperatives and other rural utilities. This series covered applicable standards, certification processes, and DOE's Competitiveness Improvement Project (CIP) to improve the cost competitiveness and reliability of smaller turbines.

Task 4: Develop Clear and Discrete Partnership Models and Open Data

Besides the topics covered in Task 3's *Development Practices Report*, the primary focus of Task 4 was on Open Data and the development of a web-based database tool. NRECA maintains a database of renewable projects owned or under contract by electric cooperatives and other member utilities, including distributed wind deployments. PNNL maintains a database of distributed wind projects nationwide in support of its annual *Distributed Wind Market Report*. NRECA Research worked with PNNL to compare these datasets and confirm which projects have co-op involvement as well as other project details. The map below shows distributed wind projects of 100 kW or larger located in the service territory of electric cooperatives or other NRECA rural utility members.

Image 6: Distributed Wind Projects (100 kilowatts+) in NRECA Members' Service Territory



This preliminary work fed into the development of a national database tool hosted by PNNL, which provides a searchable and filterable database that utilities, developers, and other stakeholders can use to locate projects of interest based on various criteria (geography, turbine type, other hybrid technologies, co-op or other utility involvement, etc.). As part of RADWIND, the database identifies projects owned or under contract by electric cooperatives based off of NRECA's database of co-op projects. Image 7 below shows some of these features. The website also features an instructional video, allows stakeholders to submit updated or corrected data on existing projects, provides instructions for stakeholders on how to submit new or corrected data on projects, and allows downloading of the complete dataset which includes additional data fields for these projects. NRECA Research created a subpage to cross-post this resource, including the map above and the recording of an instructional webinar targeted at NRECA members.

Image 7: PNNL Distributed Wind Database Showing Fields and Filters

SEARCH

APPLY

2676 results found

Project Name ▲	County	State	Year Online	Project Capacity (kW)	Turbine Nominal Capacity (kW) [Units]	Turbine Manufacturer / Model Name	Hybrid Type (Other DERs)	Installer or Developer	Owner / Power Purchaser
1800-Law-Firm		MI	2014	4.00	1.00 [4]	UGE International / eddyGT		SRInergy LLC	1-800 Law Firm /
30 MW Iowa DG Portfolio		IA	2017	30,000.00	3,000.00 [10]	Nordex / AW125/3000		Optimum Renewables	Building Energy Wind Iowa / Interstate Power & Light Company
3BarG	Kittitas	WA	2011	120.00	120.00 [1]	Vestas / V20			
AC Baughman, Inc.		IA	2012						
Ada School	Hardin	OH	2011	400.00	400.00 [1]	Turbowinds /		NexGen Energy Partners	NexGen Energy / Ada School
Adams Auto Upholstery	Mitchell	IA	2011	20.00	20.00 [1]	WTIC / Jacobs 31-20		One Energy LLC	

FILTER BY STATE

- AK
- AL
- AR
- AZ
- CA

Show more

FILTER BY TURBINE MANUFACTURER

- AAER/Pioneer Wind Energy Systems
- Abundant Renewable Energy
- Acciona
- Aeroman
- Aeronautica

Task 4 also called for the submission of an article or manuscript to a peer reviewed journal with a subject matter relevant to rural distributed wind. The nature of the RADWIND project did not lend itself to an article in a technical journal. In lieu of this deliverable, NRECA Research has worked with *RE Magazine* to publicize three short articles featuring RADWIND and distributed wind related content and will continue to look for opportunities to publicize this topic in the future.

A final resource developed by the Project Team is the Distributed Wind Toolkit. This toolkit aims to distill the learnings of the RADWIND reports and other resources into five educational "modules" aimed at cooperatives considering distributed wind. The first two modules were completed in 2021, and the last three are in final development by NRECA Research and Hoss Consulting and should be completed in the third quarter of 2023.

Image 8: Distributed Wind Toolkit Modules

Resources for Co-ops

1. Would distributed wind work for us?
How distributed wind works with answers to common questions

2. What would it look like here?
Information to help you scope and explore wind options

3. How do we make it work?*
** Coming Soon*
Resources to build a business plan for your wind project

4. How do we build it?*
** Coming Soon*
Suggestions for managing and executing a distributed wind project

5. How do we make it last?*
** Coming Soon*
Maintenance, operations and other issues

Project Takeaways and Lessons Learned

This section highlights major insights from the RADWIND project, based both on project resources and on the experience of the Project Team over the life of the project.

Co-op Interest in Distributed Wind Deployment is Limited, but with Opportunities for Growth

NRECA's members currently deploy a portfolio of over 9.3 gigawatts of wind capacity, of which 218 megawatts is considered distributed at various scales. Ownership is more common than PPAs at the distributed scale, with just over one-third of capacity at owned projects compared to just 5% for the overall wind portfolio. This is mostly from front-of-meter deployments; data on behind-the-meter, especially smaller installations, is not readily available.

The RADWIND surveys and the experience of the Project Team found that there is currently limited interest in distributed wind deployment as a front-of-meter utility-scale resource by electric cooperatives. At base, this stems from a perceived lack of interest among cooperative and other rural utility consumer-members in the technology. Increased public interest among consumer-members was a major driver of solar growth at electric cooperatives over the last decade. This was often supported by local and national organizations that promoted solar deployment specifically, rather than renewables in general. There were also some bad experiences with fly by night manufacturers that left many orphaned turbines unsupported, contributing to an impression that distributed wind turbines are unreliable and difficult to repair.

Nevertheless, as shown in RADWIND project case studies, where cooperatives and other rural utilities have deployed utility-scale distributed wind turbines, support has generally been strong among consumer-members. There is also the tendency of projects to "cluster," as cooperatives within a state follow their neighbors in deploying projects, especially where there is a trusted developer in the state or region able to duplicate these projects. As member-owned utilities, cooperatives would benefit from greater public awareness among the membership about distributed wind at all scales for wider distributed wind deployment. The shift of many major renewable advocacy groups away from advocating for a single technology could also help, especially where there are opportunities to include wind in hybrid projects utilizing multiple complimentary technologies.

Utility-scale distributed wind is cost competitive with solar at a similar scale, and costs are low enough to allow it to serve as a price hedge against rising wholesale power costs. While distributed wind's Levelized Cost of Energy (LCOE) is still higher than larger scale wind, this can be offset by other benefits from a smaller project, including local economic development impacts, increased local resiliency, community access to renewable energy, and avoiding transmission interconnection backlogs. RADWIND's resources highlighted these benefits, but there is an ongoing need for advocates and the industry to continue to clearly explain and quantify these features.

One major value stream that has been identified in case studies and project research is the ability of distributed wind to reduce the need for expensive wholesale power (which can include energy, capacity, and transmission charges) during times of peak demand. This value stream is one that has been proven to make utility-scale distributed wind projects economically attractive. Unlike some other value streams from ancillary services, which face challenges of technological maturity and market design, this is a value stream that can be monetized today under current market structures.

Peak reduction is also a common benefit cited for utility-scale distributed solar PV development, and the calculations are fairly simple based on geography and solar availability, with different array "tilts" used to help shift production to when it is most valuable. Wind resources are more granular and more challenging to predict, but it would be useful to have a high-level screening tool for use by consumers, developers, and utilities showing the alignment of expected wind production with daily and seasonal peak demand periods, especially during winter when wind tends to produce more while solar production is reduced. The variation in turbine size and tower height makes this more challenging than with solar, but generally this tool would probably be most useful for projects using large-scale turbines, which when well-sited can significantly reduce demand on an entire distribution feeder when producing during peak times.

While distributed wind, whether synchronous or inverter-based, offers increasing technical potential to provide ancillary services to the grid like frequency response and voltage support, these potential services are often not compensated in current wholesale and distribution market designs. If these services were compensated and monetizable, then they might offer attractive additional revenue/value streams for distributed wind deployment.

Most distribution cooperatives and other rural distribution utilities have an all-requirements contract (ARC) with a G&T or other primary provider of wholesale electricity. These requirements make varying allowances for the development of distributed generation outside of the ARC based on energy and/or capacity. There is great variation across the country in these allowances, and in many cases, they are evolving. Developers should reach out early to electric distribution cooperatives or other rural distribution utilities to understand the opportunities and constraints for DG development on their systems and be open to the possibility of bringing the G&T into these conversations.

There is the potential for innovative partnerships between distribution cooperatives and their G&Ts to find solutions that conform to or circumvent these limits, as has been seen in the joint development of distributed utility-scale PV. These partnerships can also have the benefit of offering potential for aggregation and increased benefits of scale with the deployment of multiple standardized projects, which can also help address equity issues, better integrate resources into resource planning efforts, and maximize locational value on the grid. G&Ts often put out requests for proposal (RFPs)[3] for renewable capacity, which might offer an opportunity to propose an innovative aggregation of distributed wind resources in lieu of a larger transmission interconnected wind farm.

Given the wide variety of turbine sizes and design, distributed wind installations are less standardized/scalable than solar PV. RADWIND profiled some examples of standardized designs from regional developers, but the lack of developers with a national footprint is also a challenge to greater standardization. This is even more true in the hybrid space, where no single design of wind-centered hybrid project has been deployed widely. A greater degree of standardization might make these projects

[3] Many G&Ts and some distribution cooperatives work with the National Renewables Cooperative Organization (NRCO) on these RFPs, see https://nrco.coop/.

more attractive for electric cooperatives, including G&T cooperatives that might choose to deploy several projects across their territory.

Electric cooperative leaders are concerned about grid reliability and affordability as the national electric grid transitions. While intermittent renewables like wind and solar have been great sources of inexpensive energy, they are not dispatchable and thus have lower capacity value than traditional generation resources that are available when needed, a challenge which increases at higher levels of deployment. This is where hybridization offers the greatest potential. Combining wind and solar has the potential to increases the likelihood that production will coincide with daily and seasonal peaks, and the addition of battery storage adds a degree of dispatchability that can create greater assurance from a reliability standpoint.

Both RADWIND surveys indicated that the potential for hybridization increases interest in distributed wind, with battery storage particularly attractive. While costs of these systems have been high, the new tax credits which both restore credits for wind technologies on par with solar and add a separate tax credit for battery storage which removes the bias towards solar charging are very promising developments. If these tax credits spur a wider deployment of hybrid wind projects at the distribution scale, that should improve economics and make these a more bankable resource for electric cooperatives.

Finding Win-Win Solutions for Behind-the-Meter Distributed Wind

If the Project Team could offer one piece of advice to developers, it would be to reach out to the local electric cooperative or other rural utility early, even for behind-the-meter projects, so that there is awareness on both sides about what to expect regarding interconnection, system impacts, and potential benefits and challenges.

Co-op staff and leadership are generally more knowledgeable about rooftop and other small-scale solar than small-scale distributed wind. More resources are needed to allow staff to understand the current state of distributed wind technology to advise consumer-members. The RADWIND advisories on small- and medium-scale turbine standards, certification, and the CIP are a start, but ultimately the original equipment manufacturer (OEM) or their licensed vendors are the best source of education for co-op staff and leadership.

One potential pitfall consumer-owned distributed wind projects, especially for smaller BTM deployments, is the inaccurate energy production or financial cash flow/pay-off information, which can lead consumer-members to blame the co-op when actual performance falls below expectation. Cooperatives generally have clear information on their rates and rate structures by consumer class posted on their website, but OEMs and developers are encouraged to reach out to the local co-op before marketing their products to consumer-members. The RADWIND Project Team suggests that cooperatives also clearly post their requirements for interconnection for behind-the-meter projects, as well as compensation methods for excess generation (e.g., net metering, avoided cost, value payment, etc.), on their websites and keep this information updated. Doing so is likely to be increasingly important as some businesses may seek to reduce energy costs by owning a portion of their electrical generation needs to hedge against increasing electricity rates or to meet corporate sustainability goals.

There is also a lack of easy-to-use screening tools (similar to PVWatts) for distributed wind, especially for small- and medium-scale turbines. Like PVWatts, this tool would need to be accessible to homeowners and small building owners who are interested in distributed renewable generation and might be open to wind as a technology option. This would be a valuable tool to get a more granular analysis than simply using national wind maps and could also better account for varying tower heights and turbine scales.

For rural utilities or consumers that rely on manufacturers or manufacturer-certified technicians to perform non-basic maintenance on wind turbines, there is a challenge of availability of maintenance contractors and/or their ability to address issues in a timely manner. This is a more significant issue with smaller turbines, where maintenance providers often lack a national footprint, and remote areas with a low concentration of distributed wind turbines.

In general, negative experiences with a previous generation of small wind technologies and the slow pace of deployment of improved small wind turbines have exacerbated a lack of consumer interest, as there is a lack of an installer base and maintenance technicians familiar with various models in or near many cooperative territories, even though they might be in areas where large transmission-tied wind farms are common. The importance of certification and improved technologies driven in part by programs like the CIP are worth highlighting to build confidence in smaller scale wind technologies.

Defining a Role for Distributed Wind

In general, efforts should be made to emphasize the particular benefits that distributed wind can provide locally, regionally, and nationally; what problems it can solve, and its particular strengths either on its own or as a complement to other technologies.

Efforts like the *Distributed Wind Futures Study* have identified huge technical and economic potential for distributed wind on both sides of the electric meter, but it does not compare it to other options (except similarly scaled solar PV) or address how it would be integrated with existing resources on both the distribution and transmission side of the grid into an overall power supply portfolio. This type of analysis could also be used to highlight particular strengths of distributed wind and distributed wind hybrids vis-à-vis large transmission-tied projects, especially given constraints on interconnections of these resources and transmission expansion.

Current market trends and projections still show bulk-scale generators making up the majority of new capacity. That still leaves significant room for growth of distributed generation, including distributed wind, but an articulation of the benefits of these resources and how they complement other technologies in an evolving electric grid under various scenarios would be helpful. This would not preclude options for a far more decentralized grid with a significant contribution from distributed wind but could help ground market development in a more realistic and future-proofed way.

Distributed wind’s role in increasing community resiliency should also be emphasized. As large wildfires and storms increasingly impact transmission grids and fuel supply, especially in rural and remote areas, the deployment of local generation assets can offer a solution to maintaining reliability and resilience on local grids. Microgrids pairing solar PV with battery storage and fossil backup generation is a resilience solution being deployed in many communities, while wind components are far less common, especially outside of Alaska. In many areas, wind has potential to add significant resilience value to microgrids, most importantly though its ability to generate energy overnight and on cloudy days when solar output is limited, reducing the demand on limited duration battery storage and fuel-limited backup generators.

There are also opportunities for integrating distributed wind or distributed wind hybrids with other behind the meter DER on the same distribution grid. For example, in one deployment case study, RADWIND highlighted a co-op that was piloting the use of grid-enabled water heaters in members' homes as a virtual, distributed battery that could store excess wind energy as needed thereby reducing on-peak water heater energy consumption. Electric cooperative microgrid deployments have also utilized water heating and HVAC controls to offer a demand side compliment to microgrid generation assets.

Besides hybridization and microgrids, there are opportunities for other business models like "community wind" where a portion of the output could be purchased and assigned to individual consumer-members in lieu of a wind-turbine or solar panels at their home or businesses. Pairing on-site distributed wind with EV charging could also be attractive, where wind production overnight offers it an advantage over solar generation, or another opportunity for hybridization with both technologies.

Scale creep could create challenges for deploying large-scale wind turbines on rural distribution grids. Projects using large-scale (1 megawatt or larger) are generally the most economically competitive. Typically, these projects utilize the same models of turbines being used by large transmission-tied wind farms. The "baseline" size of large onshore turbines has grown—from 1.5 megawatts several years ago to 2.8 megawatts today—with even larger turbines becoming more common. Increasing turbine capacity and hub height has generally led to higher output and lower energy costs, but it does present challenges. Notably, smaller rural substations might not be able to accommodate the larger units, especially where back feeding onto the transmission grid is a concern. This could offer an opportunity technologically advanced and cost competitive medium-scale or smaller large-scale wind turbines specifically targeted at these areas where larger turbines can not be accommodated.

Also, there appears to be increasing local opposition to new renewable projects of all kinds in many parts of the nation, particularly in areas that have already seen widespread deployment. This increase in Not In My Back Yard (NIMBY) opposition has led local governments to delay or halt projects. Specific to wind, this opposition can involve perceived issues with sightlines/viewshed, shadow flicker, wildlife impacts, sound, light pollution (from aircraft warning lights), and diverting land from agricultural use. While these concerns might also apply to distributed-scale wind to some degree, there may be an opportunity to make the smaller size of these projects a positive selling point in some areas when compared to large transmission-level projects. The first-hand experiences of communities profiled in RADWIND case studies could be highly beneficial in this area—only one community experienced notable opposition to distributed wind turbines, and the complaints about adverse effects of wind turbines that were not able to be verified with credible scientific measurements.

Conclusions and Future Opportunities

RADWIND showed that distributed wind has been succesfully deployed in a variety of ways by electric cooperatives and other rural utilities across much of the country, and that there is significant potential for growth. Once these projects are developed, consumer-members and utilities are typically very pleased to host these projects in their rural communities and benefit from rate stabalization, increased resiliency, community education opportunities, and additional local property taxes.

As the *Distributed Wind Futures Study* and other recent research has shown, there is great but unrealized potential to expand cost-effective distributed wind capacity in the U.S. Rather than a single barrier that many new technologies face, like high cost or unvetted technology, distributed wind is inhibited by a variety of surmountable barriers. Today, many rural utilities and consumer-members are comfortable with distributed solar generation, and its lack of moving parts is appealing from a maintenance perspective. Compounding this are outdated perceptions of performance and reliability of wind turbines used in distributed applications. Bad experiences decades ago with small wind turbines that failed early and manufacturers that went out of business and left customers to their own devices still colors the perception of distributed wind.

Today, operations and maintenance (O&M) remains a barrier in many areas served by rural utilities as the low concentration of distributed wind turbines does not warrant full-time technicians located in these regions and easily available. As a result, some highly motivated co-ops interviewed for RADWIND train existing maintenance staff and line workers to also climb and maintain wind turbines. Others promote solar to members given the lack of availability of small wind installers and maintenance providers. And although RADWIND and other efforts have shown that larger distributed wind projects can hedge or reduce wholesale power costs for rural utilities, small utilities often do not have extra staff capacity to research, plan, and secure financing for these projects. More than one cooperative highlighted the value of having access to a trusted, local developer that understood the environment in which rural distribution utilities operate to bring successful distributed wind projects to fruition.

Recent changes in federal policy stemming from the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA) will enable new opportunities for distributed wind. This funding includes billions of dollars in grants, loans, and awards available for distributed renewable energy, including distributed wind, as well as extensions for the Business Energy Investment Tax Credit (ITC) and Production Tax Credit (PTC) which can significantly improve the economics for distributed wind projects, as well as multi-technology hybrid projects.

Particularly releveant to rural utilities are ITC stackable “bonuses” for projects located in “energy communities,” and for projects that serve low-income communities. Further, for distributed-scale projects, there are additional bonus credit opportunities available for projects up to 5 MW that serve low-income or tribal communities. The ITC also allows for the inclusion of interconnection costs for projects up to 5 MW. Smaller projects of 1 MW or less are exempted from the prevailing wage and apprenticeship requirements that larger projects must meet to access the full tax credit amount.

These extended tax credits also include “direct pay,” also known as “elective pay,” provisions that allow not-for-profit utilities like electric cooperatives and rural public power districts, as well as other rural non-profit entities, to directly access them for the first time. Another provision, “transferability,” allows for-profit entities without sufficient tax appetite to sell the tax credits to an unrelated third-party. Both of these provisions can greatly simplify financing of distribued wind projects, without the complicated "tax equity" models necessary under the prior version of the tax credits.

Outside of tax incentives, new federal grants for renewable projects serving rural areas are also significant. Many opportunities could support distributed wind expantion, including:

- DOE's Office of Clean Energy Demonstration's (OCED's) Energy Improvements in Rural and Remote Areas and Clean Energy Demonstration Program on Current and Former Mine Land grants[4]
- USDA's Empowering Rural America (New ERA) Program[5]
- Expansions to existing programs like USDA's Rural Energy for America Program (REAP) and DOE loan guarantees

RADWIND has suceeded in building a base of knowledge and a presence in the distributed wind space by NRECA on behalf of its members. Going forward, NRECA Research is participating in the On Site Wind for Rural Load Centers project led by Idaho National Lab (INL), as well as ongoing partnerships with PNNL on their distributed wind data work and reporting.

NRECA Research will continue to monitor opportunities and developments in this space, and plans to utilize the networks developed through RADWIND to dissiminate information and resources to NRECA's membership and gauge member interest in future research, development, and deployment opportunities. A key area for interest for NRECA Reseach is the inclusion of distributed wind into hybrid projects, including microgrids, to leverage the complementary nature of wind and solar generation with storage (battery, water heaters, etc.) to maximize the value to co-ops and rural communities and provide reliable and resilient power when and where it is needed on the distribution grid.

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[4] https://www.energy.gov/oced/oced-funding-information
[5] https://www.rd.usda.gov/programs-services/electric-programs/empowering-rural-america-new-era-program

Appendix: Publications and Other Project Resources

All project resources can be found on the project landing page using the simplified weblink https://www.cooperative.com/radwind.[6] Many resources also include subpages with resource summaries and other information. Below are citations and direct weblinks to these resources.

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