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Distributed Wind Project Development Practices in Rural Electric Cooperative Service Areas

NRECA
America's Electric Cooperatives

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RADWIND PROJECT REPORT SERIES: Distributed Wind Project Development Practices in Rural Electric Cooperative Service Areas

Prepared By:

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Continued…

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Background

Developing Distributed Wind Projects in Rural Electric Cooperative Service Areas is part of a series of NRECA Research's Rural Area Distributed Wind Integration Network Development (RADWIND) project reports about wind as a distributed energy resource (DER).

The RADWIND Project

The RADWIND project seeks to understand, address, and reduce the technical risks and market barriers to distributed wind adoption by rural utilities. More than 20 co-ops and rural utilities have participated in the RADWIND program as project advisors or in other roles, such as being case study subjects or joining conference calls with the project team. The goal of the project is to reduce the barriers for distributed wind deployment, either as a standalone resource or as part of a hybrid power plant with other DER. Additionally, the RADWIND project aims to provide resources that enable cooperatives to be the first contact and trusted advisor for their member-owners[1] considering distributed wind.

Many co-ops participating in the RADWIND project indicate interest in deploying or supporting deployment of distributed wind in their territories to reduce energy costs, provide local energy security, increase economic development, and satisfy member-owner interest in local renewable energy. This report is designed to support electric cooperatives and other rural utilities[2] as they explore and pursue distributed wind deployments by explaining the processes by which projects are screened, developed, and financed.

This report complements the preceding RADWIND reports:

Use Cases for Distributed Wind in Rural Electric Cooperative Service Areas (hereafter "RADWIND Use Cases Report")

Value Case for Distributed Wind in Rural Electric Cooperative Service Areas (hereafter "RADWIND Value Case Report")

Financing Distributed Wind Projects in Rural Electric Cooperative Service Areas (hereafter "RADWIND Finance Report")

Business Case for Distributed Wind in Rural Electric Cooperative Service Areas (hereafter "RADWIND Business Case Report")

These reports are available on the project landing page at www.cooperative.com/radwind.

[1] NRECA reports often refer to the "consumer-members" of a cooperative, but other terms such as "member-owners," "customer-owners," or simply "members" are common in the literature. This report will refer to them primarily as "member-owners" and "members."

[2] While this report generally uses "cooperatives" or "co-ops," NRECA's membership also includes more than 40 utilities that are not organized as cooperatives, mostly rural public power districts as well as small municipal, tribal, and mutual utilities. Though business models differ, this report should be applicable to them as well as other rural utilities that are not NRECA members.

Defining Distributed Wind

As detailed in the RADWIND Use Cases Report, distributed wind projects can use any scale of wind turbine. “Small” turbines have up through 100 kW generating capacity. “Mid-sized” or “medium-sized” turbines can generate between 101 kW and 999 kW, and “large” machines have 1 MW or greater generating capacity (Orrell, 2021). A wind energy asset is considered “distributed” based on its proximity to end use and its interconnection point (Orrell, 2021). Front-of-the-meter distributed wind projects are connected to the distribution grid and are part of the overall power supply portfolio for all grid-connected loads but are not generally expected to feed power back to the transmission grid. Behind-the-meter projects are located behind a co-op’s or other utility’s member-owner’s revenue meter and are sized to serve on-site loads; excess energy may enter the distribution grid depending on the project size, the relevant load profiles, and the cooperative’s billing mechanisms. Off-grid distributed wind turbines can serve a variety of loads in a range of sizes, but they do not connect to a distribution or transmission grid.

Introduction: The Role of Cooperatives in Distributed Wind Development

This report serves as a high-level overview 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.

As a technology, distributed wind's modern roots date back nearly a century, predating even the current U.S. Rural Electric Cooperative model. More recently, technology advancements have strengthened the business case for grid-connected distributed wind systems, and the Inflation Reduction Act of 2022's (IRA) renewable generation financial incentives augment that case further (*Electric Co-Ops Cheer Inclusion of Key Co-Op Priorities in Senate-Passed Inflation Reduction Act*, 2022). As a result, the opportunities for distributed wind deployment in the U.S. are growing. The total potential for the technology is substantial. The National Renewable Energy Laboratory (NREL) estimates nearly 1,400 GW of economic potential for distributed wind exists now with several terawatts more of profitable generation to be available by 2035 (McCabe et al., 2022).

The RADWIND Value Case Report[3] lays out the variety of value streams that distributed wind can bring to a cooperative and its member-owners, and the RADWIND Business Case Report[4] expands upon many of them. Technology trends and policy changes in just the last few years make distributed wind deployment an even more compelling distributed energy resource (DER) option for electric cooperatives. Listed here are selected value propositions, technology developments, and policy reforms that make a case for co-ops to examine distributed wind development options:

Table 1: Confluence of select value streams, technology considerations, and energy policies that enhance the distributed wind value proposition for electric cooperatives

Value Streams	Technology Considerations	Policies
• Peak demand reduction	• Wind-PV Solar hybrid plants based on resource complementarity (see NRECA tech advisory[5])	• IRA: Tax credit direct pay option facilitates asset ownership by cooperatives
• Energy price stability and hedge against rising energy costs	• Small and medium-sized turbine price decreases (see NRECA tech advisory[6])	• IRA: Extended tax credits for 10 years minimum

[3] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Value-Case-Report-May-2021.pdf

[4] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Report-Business-Case-April-2022.pdf

[5] https://www.cooperative.com/programs-services/bts/radwind/Documents/Advisory-RADWIND-NREL-Wind-Solar-Complementarity-June-2022.pdf

[6] https://www.cooperative.com/programs-services/bts/radwind/Pages/Improving-Cost-Competitiveness-of-Small-and-Medium-Wind-Turbines-.aspx

• Distribution system resilience	• Component of emerging microgrid solutions	• IRA: Low-cost capital for clean energy projects in cooperative territories
• Deferred distribution system infrastructure investments	• Wind-Battery Energy Storage System (BESS) hybrids as battery prices decrease	
• Direct revenue streams (see “Policies” list)	• Faster deployment avoids transmission interconnection wait time, supplements larger G&T PPA projects	
• Member-owner satisfaction		

RADWIND listening sessions and other conversations with cooperative leaders suggest that while the IRA’s new direct pay provisions may increase the number of distributed wind projects directly owned by co-ops, professional developers would still be necessary to oversee project screening, development, installation, and commissioning. Thus, there is value in cooperatives understanding how projects proposed for their networks come to fruition. When cooperatives have context for the technical, environmental, and social aspects of those projects they can collaborate with the developer to expedite the development process and act as trusted energy advisors to their member-owners before, during, and after the project is completed. The following list lays out a few ways that co-ops can play a vital role:

1. Set project parameters: What is the project's purpose? Which members will the project serve? What values will it bring? Which value streams are top priority?
2. Assess the project’s business case
3. Understand financing options
4. Proactively reduce project risk (see the RADWIND Finance Report[7] for suggestions)
5. Become familiar with the screening, development, and costs of a project

Pursuant to the last point, this report first explains the project screening process with an emphasis on wind resource assessment. Then, the stages of a distributed wind project’s lifecycle are discussed. Methods for estimating Annual Energy Production (AEP) are included in this section. Finally, the report outlines the costs associated with distributed wind development and the types of cash flows that a cooperative can expect when a distributed wind asset enters service.

[7] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Finance-Methods-Report-August-2021.pdf

Project Screening

Distributed wind projects begin with a series of screening steps that ensure any constraints that render the project unfeasible are identified early. There are several typical go/no-go decision points in the project development process. The earliest decision points occur while prospecting for potential project sites. If, for example, a local permitting ordinance requires setbacks incompatible with the available land, there is little justification for investing in a wind resource study. Similarly, the project's cost and complexity may prove unsustainable if a critical habitat or species is discovered at the project site or if unique soil conditions necessitate a prohibitively expensive, exotic tower foundation. Later go/no-go decisions are usually based on the project's expected financial performance. Additional resource studies and design refinements improve the accuracy of cost and performance estimates, and each incremental engineering investment must be justified by an expected improvement in the project's viability. This section explains the typical site screening steps with an emphasis on wind resource assessment (WRA).

Identifying Prospective Sites

Identifying an appropriate physical location for a renewable generation asset—a wind turbine in this case—depends first on the asset's future use case. Front-of-the-meter (FTM) wind assets, for example, may be placed where its interconnection presents the most value to the distribution system. A behind-the-meter (BTM) installation, on the other hand, would generally need to utilize property belonging to the hosting consumer. For both FTM and BTM turbines, the specific location for a turbine depends on a constellation of factors.

Developers prioritize siting a FTM turbine where both the local wind resource is strong and where interconnection is feasible, meaning a point on the distribution grid with sufficient hosting capacity. Co-ops and developers should work together to identify locations with good hosting capacity early in the project. Adding a distributed battery energy storage system (BESS) as part of an FTM hybrid project may expand the number of candidate development sites, as the BESS can help manage the energy flow from the project to support grid stability. Developers also evaluate sites for their topographic and geotechnical characteristics (e.g., soil conditions) to assess its suitability for construction as well as for the presence and locations of nearby and significant obstacles (e.g., vegetation, buildings, etc.) that could interfere with the wind resource. Finally, it must be feasible to establish land control (e.g., via purchase or lease), to get the project permitted, and to avoid significant environmental and human impacts.

BTM projects, in contrast, are generally located on the property served by the host's meter, though virtual net metering situations may have the turbine located on a separate land parcel. The same factors that influence FTM siting are also considered with a BTM installation, with the added complexity of avoiding negative impacts on land use or enjoyment of the host's property. BTM projects also tend to host smaller turbines with shorter towers, increasing the need for careful siting around objects. For off-grid projects, the same factors apply, but the turbine's proximity to the load being served becomes increasingly important to avoid electrical line costs that a smaller turbine's higher cost per kW cannot justify.

In each case, it is common to consider a variety of locations and to weigh the relative cost and benefit of each candidate site. For multi-turbine projects, it is also important to assess different possible layouts within the project footprint. It is also common to delay the turbine make and model selection until later in the project design process, especially for projects utilizing larger turbines for which there are a larger number of turbine options. The cost and conditions of turbine supply are dynamic, so the developer can make the highest-value selection once more pieces of the project are in place. Since wind turbine rotor size is contingent on turbine choice, the developer should finalize turbine locations and layouts that are compatible with the final turbine geometric specifications such as the rotor diameter and tower height.

Wind Resource Assessment

Many factors determine a distributed wind project's financial viability, but among the most important is an understanding of how much energy the project is likely to produce and when. This value, in turn, depends to large extent on the wind speed and its variability at a potential project site. The process of measuring and analyzing a site's wind pattern is called wind resource assessment (WRA), and this section of the report describes how it is accomplished. More details on characterizing a wind resource and estimating energy production can be found in Appendix B and Appendix C, respectively.

Mesoscale Analysis

> ***What the experts say…***
>
> *(experts quoted in this paper are Contributing Authors credited in the introductory pages)*
>
> *Mesoscale models can certainly produce high-quality, low-uncertainty wind energy estimates that are acceptable to [lenders] if done correctly by a reputable and experienced organization and with proper use of high-quality observations.*
>
> Mark Stoelinga
> ArcVera Renewables

As a first step to a wind resource assessment, areas with suitable wind resources can be identified or confirmed using a "mesoscale" wind resource model, often referred to as a "wind map." Requiring no field equipment, this desktop approach is a cost and time-efficient means of resource screening. "Mesoscale" refers to the scale of the numerical weather prediction model (NWP) used to estimate wind patterns, the results of which are delivered by a resource assessment consultant or via a web application. As "meso" means "middle", the model's scale leaves out the largest system (i.e., the entire atmosphere) and the smallest wind patterns (i.e., the flow and resulting turbulence around small objects on the ground). Instead, the model ranges from a weather system that creates wind down to wind flow around large geographic features like mountains, large bodies of water, and coastlines. Mesoscale models take their inputs from global weather models such as NASA's MERRA-2[8] which incorporate real-time measurements from radar, surface weather stations, atmospheric weather stations, and even sensors on

[8] https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

aircraft and ships. When surface roughness and terrain information are included in the model it can estimate wind speeds in each cell, or square, of territory, typically measuring a few kilometers on each side. Cooperatives may wish to explore NREL's Wind Integration National Dataset Toolkit[9] to see mesoscale models in their territory.

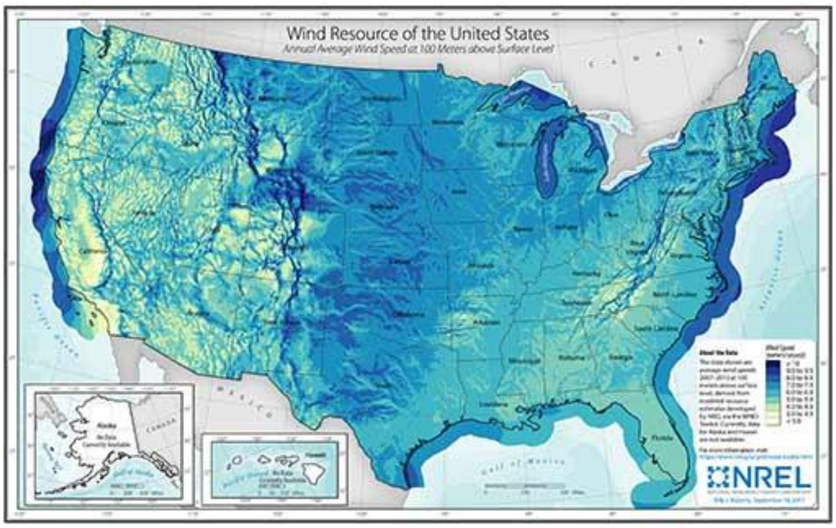


Figure 1-a

Mesoscale wind resource map of the United States at 100 m above ground level
(Draxl et al., 2015)

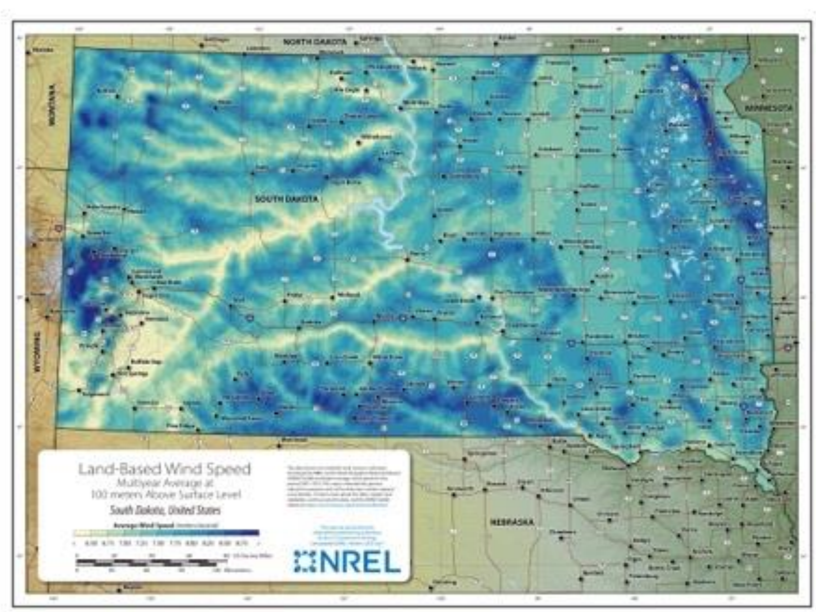


Figure 2-b

Mesoscale wind resource map of South Dakota at 100 m above ground level
(*Wind Energy in South Dakota,* n.d.)

https://www.nrel.gov/gis/wind-resource-maps.html

and
https://windexchange.energy.gov/states/sd

Output from mesoscale models appears as annual average wind speeds for an area with a resolution from a hundred square meters to a few square kilometers, a wind rose[10] that indicates the predominant wind

[9] https://www.nrel.gov/grid/wind-toolkit.html

[10] For an example of a wind rose, see Figure 2 on page 10.

directions, and a seasonal estimate of wind speeds. This output can be sufficient to understand wind resource strength at a prospective project location and can help identify candidate tower locations around major obstacles. Additional modeling may be necessary—even for small projects—to understand the effects of local geographic features or ground-level obstructions that are too small to be included in the terrain model.

In projects where debt is non-collateralized, such as mid-sized and larger projects that utilize project finance structures, additional modeling may be needed to predict annual energy production more accurately. This helps lenders quantify perceived risks. These additional modeling efforts closely examine project-level terrain, obstructions, and high-resolution information about ground cover type. Known as “virtual meteorological masts” (VMM) or “high-resolution site wind resource maps,” these models have been shown to be highly accurate when produced by experienced and skilled experts. VMMs typically only provide information about a specific point whereas model outputs in the form of a map can provide insights that are useful for fine tuning the position of the proposed wind turbine within a candidate area.

Finally, for certain projects, an on-site resource assessment campaign may be warranted. Usually these campaigns last at least one year and utilize a hub-height meteorological tower or a remote sensing system. Both approaches continuously measure wind speeds and directions at different heights to capture the wind flow patterns at the project site. On-site measurements help reduce a model’s uncertainty, which in turn improves its long-term accuracy when correlated with historical data (see Appendix B for information).

What the experts say…

[For large projects with greater financial investment] Mesoscale models should always be used in conjunction with on-site observations to…determine the spatial uncertainty of the model’s mean wind speeds.

Mark Stoelinga
ArcVera Renewables

Micro-Siting

When topographic or ground level obstructions and features are present at a proposed project site, a developer would typically take additional siting steps to maximize the benefits and minimize the negative effects of topography and obstructions. Developers may use micro siting tools like computational fluid dynamic (CFD) models and local numeric weather prediction models built to incorporate on-site topographic and ground features. There can be increased tolerance for production estimate uncertainty for smaller projects where the magnitude of the project cost can be significantly less than the value of the land and/or load they support. In these cases, simpler linear models of obstruction influence, such as the Perera model,[11] may be used to save time and money. Adjustments to preconstruction energy production estimates for ground-level obstructions also account for seasonal and directional wind speed patterns and how these flow patterns interact with those obstructions. These patterns are essential for estimating gross production as well as the energy loss attributable to each obstruction. Information that is included in this type of analysis includes:

[11] Named for the paper by M.D.A.E.S Perera: *Shelter behind two-dimensional solid and porous fences,* found at https://linkinghub.elsevier.com/retrieve/pii/0167610581900106

- Wind rose showing the frequency of each wind direction
- Dimensions and location of buildings
- Ground cover type in each direction

The height of a distributed wind turbine tower is often limited by the cash flow that can be produced by the turbine, meaning a small turbine that produces a few thousands of dollars of value each year cannot justify the expense of a tall tower that may cost tens of thousands of dollars. Large-scale wind turbines (1 MW+) that can generate hundreds of thousands of dollars in value per year can utilize the same 80-100 meter towers found in larger wind farms. Mid-scale wind turbines (101-999 kW) may be limited to towers at or below 80 meters tall, and small-turbines 100 kW or below will often have towers 36 meters (and less) in height. Tower type also influences height. Lattice towers can deliver more height than tubular towers for the same cost, though lattice towers have larger footprints. To appreciate how tall a tower must be to elevate a turbine above ground clutter effects, developers sometimes start with a rule of thumb: a wind turbine tower should be at least twice the height of the tallest nearby obstruction in the windward direction. While taller towers typically reach stronger, steadier winds and are thus less impacted by ground-level obstructions shorter than 30 meters (100 feet) tall, there are advantages to small turbines and shorter towers in that they have smaller footprints, easier logistics, require smaller installation and service cranes, and result in reduced visual impact. Shorter towers, as mentioned before, require more care in siting to ensure that production estimates accurately account for the influence of ground-level obstructions on energy production.

What the experts say…

Complex project sites—those with many obstacles and/or complicated terrain—increase error in energy production estimates. Turbines on shorter towers will see greater error than those on tall towers.

Heidi Tinnesand
NREL

What the experts say…

Meso-scale WRA can tell you which areas are feasible for development and where to explore, but they don't give you siting information. They also do not optimize a turbine's location relative to economic factors like tower height or cable length.

Heidi Tinnesand
NREL

What the experts say…

Future micro-siting tools will interpolate meso-scale wind resources data and combine that information with digital maps of buildings and terrain. The output will give developers and project hosts a higher-resolution picture of the wind resource within a potential project site.

Heidi Tinnesand
NREL

Other Essential Screening

In addition to wind resource screening, other screening is needed to understand permitting requirements, reduce any negative impact to neighbors and wildlife, and estimate development and construction costs. Each screening category typically involves consultations with a unique agency or jurisdiction. It is the developer's responsibility to be familiar with both the requirements for project approval and how to navigate the approval process efficiently. The host cooperative can provide value to their member-owners by supporting the developer as they secure approvals and to advise member-owners on various permitting requirements early in the process.

Environmental Screening

In collaboration with the wind industry and its stakeholders, the U.S. Fish and Wildlife Service (FWS) has established a set of voluntary guidelines for environmental screening and environmental studies. These Land-Based Wind Energy Guidelines (WEGs)[12] lay out a tiered approach that ensures that any environmental concerns are identified early. For distributed wind projects, WEGs indicate that, absent the discovery of sensitive habitat or species at the project location, only simpler pre-construction (Tier 1 and Tier 2) investigations are necessary. If sensitive habitat or species are encountered at the project site, it may be necessary to perform additional, site-specific biological studies (Tier 3) to ensure that the risk to these species or habitat are sufficiently small for the project to progress. Post-construction reviews (Tier 4 and Tier 5) are generally not required for distributed projects.

These local and site reviews are desktop studies, and they are further streamlined through FWS's Information for Planning and Consultation (IPaC) website.[13] This online tool accesses species and habitat information near the project location. Project size, location, and technology data entered into IPaC are overlaid with the FWS species and habitat database to inform distributed wind developers as they work to

What the experts say…

If landowners or community/distributed wind developers encounter problems locating information about specific sites, they can contact the Service and/or state wildlife agencies to determine potential risks to species of concern for their particular project.

American Wind Wildlife Information Center, AWWIC: https://awwic.nacse.org/.

FWS maintains IMR – the Injury and Mortality Reporting system, which is another voluntary reporting system. https://ecos.fws.gov/imr/welcome

I'd recommend checking in with state agencies and NGOs to see if they have additional recommendations. For example, The Nature Conservancy might want to make you aware of their "Site Wind Right" tool (https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/site-wind-right/) that covers the middle of the U.S. – while aimed at informing siting at larger scales, it could also have utility for distributed wind in just identifying at rough scales what potential wildlife concerns might warrant digging into.

Rachel London
FWS

[12] https://www.fws.gov/media/land-based-wind-energy-guidelines

[13] https://ipac.ecosphere.fws.gov/

avoid environmental impact. IPaC generates an automated report that can be shared with both the state and federal environmental services; the report indicates whether further investigation and coordination may be warranted. With timely notification, a developer can include the expected mitigation cost in their project financial model, commission any appropriate additional studies, and take any early mitigation steps.

In general, distributed wind turbines have a reputation for not significantly affecting the local environment, especially in their compatibility with avian species. While WEGs are voluntary, compliance is an essential part of improving our understanding of the actual impact of distributed wind projects on the environment.

Grid Screening

Experienced developers should be familiar with the interconnection requirements of the host electric cooperative before promoting or proposing a distributed wind project on that cooperative's distribution network. Grid-side constraints are revealed by an interconnection study. It is recommended for developers to work closely with the co-op on interconnection studies to ensure that all impacts to the grid are simulated through grid modeling and analysis. This allows stakeholders to develop mitigation measures for any adverse impacts. Many developers will be familiar with the challenges associated with exporting excess power from a BTM project to the distribution grid, and so they will often perform a preliminary analysis of the co-op's grid to avoid areas that are less capable of accepting energy from a member-owner's turbine(s).

Human Impact Screening

Human impacts from distributed wind energy projects include acoustic concerns and the potential for shadow flicker. Wind turbines come with expected sound levels at a given distance measured through testing. These results can be used in siting and permitting processes. Normally, local permitting rules ensure that wind turbines are sited far enough from occupied buildings to eliminate acoustic concerns. In some cases, permitting rules may have been written with large-scale wind turbines in mind, and thus these rules can result in excessive set-back requirements for smaller installations. The developer may pursue an exception to the rule if a reduced setback can be justified in such situations.
Shadow flicker results when low-angle sun shines through a moving wind turbine rotor and casts a moving shadow on a home or workplace. Like acoustic concerns, this is usually managed by local jurisdictions through mandated setbacks. The phenomenon is less pronounced for the small rotors of some distributed wind turbines because their high rotation rates create single, blurred shadows and because they are usually mounted on shorter towers.

Many developers will honor standard setbacks for sound and flicker even when not required by local regulations to reduce the likelihood of neighbor complaints. The *Distributed Wind Energy Zoning and Permitting*[14] guide from the Clean Energy States Alliance provides examples of model zoning ordinances for distributed wind.

[14] https://distributedwind.org/wp-content/uploads/2017/11/Distributed-Wind-Toolkit-Nov2017.pdf

National Environmental Policy Act Compliance

In some cases, a distributed wind project may meet the definition of a "federal nexus." This is defined as a project, activity, or program funded in whole or in part under the direct or indirect jurisdiction of a federal agency, including (*36 CFR Part 800 -- Protection of Historic Properties*, n.d.):

- those carried out by or on behalf of a federal agency,
- those carried out with federal financial assistance secured through a competitive process (i.e., not tax credits),
- those requiring a federal permit, license, or approval, and
- those subject to state or local regulation administered pursuant to a delegation or approval by a federal agency.

If a distributed wind project meets these criteria, a review under the National Environmental Policy Act (NEPA) may be triggered. This clearance process, in addition to requiring consultation with environmental agencies, may require consultation with the historic preservation offices to ensure that the proposed project does not negatively impact that character that differentiates the historic property from other properties. Developers will likely have experience with this process if they have previously accessed federal support.

Aviation Impact Screening

Projects with structures that exceed 200 feet (about 61 meters) in height require review of their structure in accordance with Title 14 of the Code of Federal Regulations (*14 CFR Part 77 -- Safe, Efficient Use, and Preservation of the Navigable Airspace*, n.d.). Projects with structures less than 200 feet tall may also need to evaluate the potential for their structure to present a navigational hazard to aircraft if they are proposed within 10,000 feet (about 3,000 m) of an active runway or heliport. The developer should:

- Use the FAA's Obstruction Evaluation/Airport Airspace Analysis (OE/AAA) Notice Criteria Tool[15] to do a preliminary screen to determine if they need to file a Notice of Construction,
- Submit a Notice of Construction at least 90-120 days before commencing construction if the turbine exceeds the height, slope, airport proximity, or other criteria limits per the Notice Criteria Tool,
- Comply with the FAA's aeronautical study determination and apply any changes to make the wind turbine installation FAA-compliant, and
- Comply with any requirements from the Department of Defense (DOD) Military Aviation and Installation Assurance Siting Clearinghouse[16]. An informal review can be requested prior to filing with the FAA.

[15] https://oeaaa.faa.gov/oeaaa/external/gisTools/gisAction.jsp

[16] https://www.acq.osd.mil/dodsc/index.html

Buildability Screening

Depending on the size and scale of a project, different features may be necessary to interconnect, access, and service the turbines. These elements are known as “balance of system” or “balance of station,” and evaluating the challenges associated with their completion is an essential screening step. Even in the presence of a strong wind resource, access issues may make the project physically impossible or financially prohibitive.

Smaller projects, including those installed off-grid, are unlikely to require special roads or laydown areas. They will, however, require foundations to be built and equipment to be delivered. Thus, even these smaller projects warrant a buildability screening to ensure there are no unique site conditions that will cause the cost of the project to grow to unacceptable levels. These include soil conditions that disallow the required turbine foundation or a site that is inaccessible or too remote for conventional means of component delivery.

Projects utilizing larger turbines may require access roads, and depending on the required construction equipment size, they may also require crane pads and improved laydown areas. Most developers will try to use existing on-site infrastructure such as roads or even parking lots, but if new construction is necessary, total project costs will increase. Demand from the wind industry has driven the introduction of larger rubber-tired cranes that can be driven to a site (as opposed to being delivered in parts on multiple trucks). Using such cranes can make the placement of large-scale turbines more affordable. The actual choice of assembly crane depends as much on crane availability as it does on capacity requirements, and the type of crane selected for a project will determine the requirement for crane access roads.

Delivering larger components, such as blades and tower sections, may also necessitate upgraded access. Vehicles carrying these elements have specific turning radius needs. Again, developers with utility-scale project experience should be familiar with these constraints and should include the cost of upgrading logistics pathway elements in their project cost estimates.

Project Screening by Use Case

The table below summarizes information on distributed wind project screening as it applies to the use cases defined in the RADWIND Use Case Report.[17]

Table 2: Distributed wind project screening categories differentiated by use case.

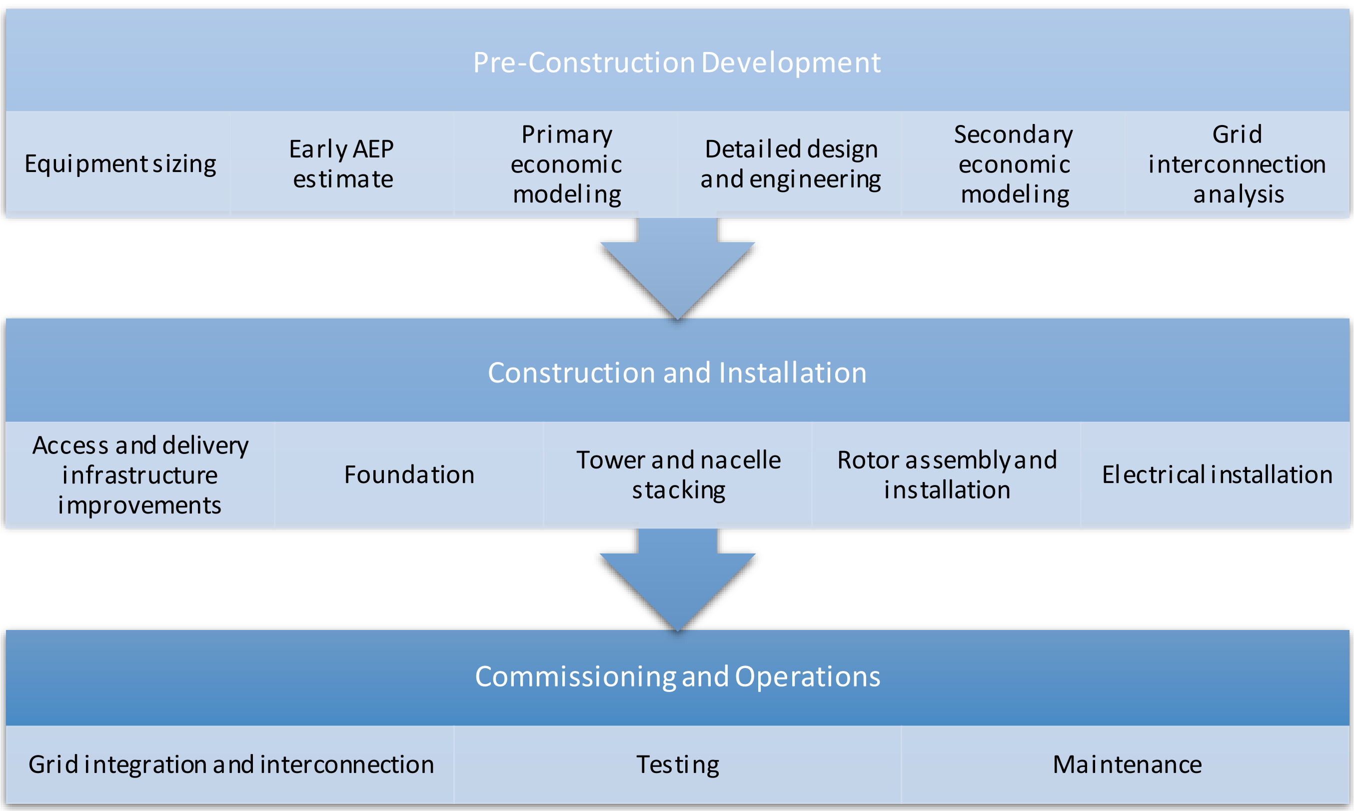
	FTM	BTM			Off-Grid
Turbine Scale	**Typically Large**	**Large**	**Medium**	**Small**	**Small**
Prospective Sites	• Strong wind resource • Feasible grid interconnection • Available land	• Strong wind resource • Host's land use preferences	• Careful micro-siting • Host's land use preferences	• Careful micro-siting • Proximity to load	• Proximity to load prioritized
Wind Resource Assessment	• Mesoscale • VMM • Onsite	• Mesoscale • VMM	• Mesoscale • Micro-siting	• Mesoscale • Micro-siting	• Mesoscale • Micro-siting
Environmental/NEPA Compliance Screening	• Tier 1 • Tier 2 • Tier 3	• Tier 1 • Tier 2 • Tier 3	• Tier 1 • Tier 2	• Tier 1 • Tier 2	• Tier 1 • Tier 2
Grid Screening	• Interconnection study	• Interconnection study	• Max export screening	• Max export screening	• N/A
Aviation/FAA Screening	• Yes	• Yes	• Maybe	• Unlikely	• Unlikely
Buildability Screening	• Access concerns such as road slope, curve radius, surface material	• Access concerns such as road slope, curve radius, surface material	• (<500 kW): Few access concerns • (over 500kW): May require large rubber-tire cranes or conventional cranes delivered by many trucks	• Few access concerns	• Access concerns unique to property

[17] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Use-Cases-Report-April-2021.pdf

Project Design and Development

Even if electric cooperatives are not developing distributed wind assets themselves, they can play a vital role as the wind developer's partner and client. As such, the development process proceeds more smoothly when cooperatives, developers, and the community at large know and understand the phases of distributed wind development. Theses phases are summarized in Figure 3. This section describes development and construction for the spectrum of turbine sizes. Additionally, the method for estimating the range of probable annual energy production values from a wind resource assessment is explained.

Figure 4: Sequence of development phases in distributed wind deployment.



Pre-Construction Development

For FTM project developers, the life cycle of a project starts with the solicitation of offers to develop and deliver a commercial project. From the perspective of the cooperative, there are steps prior to the solicitation that ultimately result in a power purchase price for delivered energy, but those steps are beyond the scope of this report.

"Distributed wind" spans a large range of project size and complexity from small, sub-kW, off-grid projects to multi-turbine FTM projects. As such, design choices also vary widely.

Equipment Sizing

The use case is the principal driver for distributed wind project design choices. For example, an FTM project generally employs wind turbines of a size and number such that the produced energy will be competitive with the value of the energy on the distribution network. Lacking the associated economies of scale, distributed wind projects have higher per-kW logistics, crane, and construction costs, as well as higher per-unit turbine and maintenance costs than those in large wind farms. Thus, extra care is needed to ensure that the proposed project can deliver energy at a cost that maintains a positive long term cash flow for the project stakeholders.

Energy produced by a BTM project in excess of the associated annual on-site load and exported to the grid is usually valued at the wholesale rate in net metering programs. The wholesale rate is typically a fraction of the delivered cost of the energy, so there is little incentive to produce more energy from a BTM project than can be consumed behind the meter within the true-up period. BTM projects, therefore, typically select wind turbines matched to the local wind resource and to the energy needs of the host site over the true-up period. Because some co-ops have complex seasonal rates, time of use tariffs, and different compensation mechanisms for excess generation, evaluating a BTM business case is an individualized and complex process. In situations with less-complex rate structures and net metering policies, calculating a project's financial fitness is simpler, but in all cases the project business model must utilize the local tariff schedule to be valid.

Pre-construction Annual Energy Production Estimate

The pre-construction energy production estimation process for large distributed wind projects mirrors the rigorous method employed by larger transmission-interconnected wind farms, but it is scaled down to fit the smaller project's land area. When a wind resource study is conducted at the prospective site, that study's results are placed in historical context to create a long-term wind resource estimate using the Measure-Correlate-Predict (MCP) method outlined in Appendix B. Combining the long-term wind resource estimate with the turbines' power curve and predicted operational losses delivers an estimated net energy production figure. This value is critical for calculating the project's delivered energy cost. Another method is to use numerical weather prediction methods to create a "synthetic" wind speed and direction record that can be used to simulate turbine output over a "standard" year. This method also requires application of loss assumptions to arrive at an estimated net energy production figure.

On the other end of the size spectrum, very small projects do not typically require the same level of rigor. The pre-construction AEP estimate can be as straightforward as calculating how many hours per year a turbine is likely to experience various wind speeds at the site based on a wind model's average wind speed and the shape of the wind speed distribution for the area. Summing the turbine's expected output at each speed over those times (called the "Method of Bins") produces a reasonably accurate AEP value, as described in Appendix C.

BTM projects in the 100s of kW range (i.e., medium sized) often utilize an approach that borrows from both ends of the size spectrum to calculate the pre-construction estimated energy production. A virtual (i.e., modeled) meteorological mast for the project location may be used, for example, instead of an on-site physical measurement campaign, to develop a preconstruction energy production estimate that is of higher value when compared to the method of bins approach. The value of the estimate is higher because the virtual meteorological mast also provides hourly wind speed direction estimates and thus can produce improved loss estimates from nearby objects. The virtual meteorological mast also delivers significant cost and time savings, when compared to an on-site meteorological measurement campaign.

When evaluating a candidate project for interconnection on behalf of a member-owner, a co-op should request that the developer show their work such that any production and revenue estimates can be properly evaluated. This would include:

- wind resource assessment findings
- calculation of gross energy production
- production estimate uncertainty figures
- assumptions about production losses (e.g., weather or technical issues) that inform a net production estimate
- temporal alignment of energy production with the tariff structure (when appropriate)
- estimates of operational and service costs

For screening purposes on all projects, the gross production figure is downgraded by expected losses before incorporation into overall project financial models. For example, a developer may estimate 8% technical availability loss from maintenance or repair with 7% site loss due to turbulence, shading, or obstruction to arrive at an estimated 15% total loss from the gross value.

The likelihood that a wind project will produce a certain amount of energy closely follows a normal distribution (see Figure 4). Points along the distribution are labeled with *probabilities of exceedance* or *P-values*. For example, the value at the distribution's peak is labeled P50 because there is a 50% chance that AEP will exceed that value each year. There is also a 50% chance that the AEP will be less than that value each year. Similarly, P90 and P99 values should be exceeded 90% and 99% of the time, respectively. P-values are essential for investors as they size their capital contributions to a project.

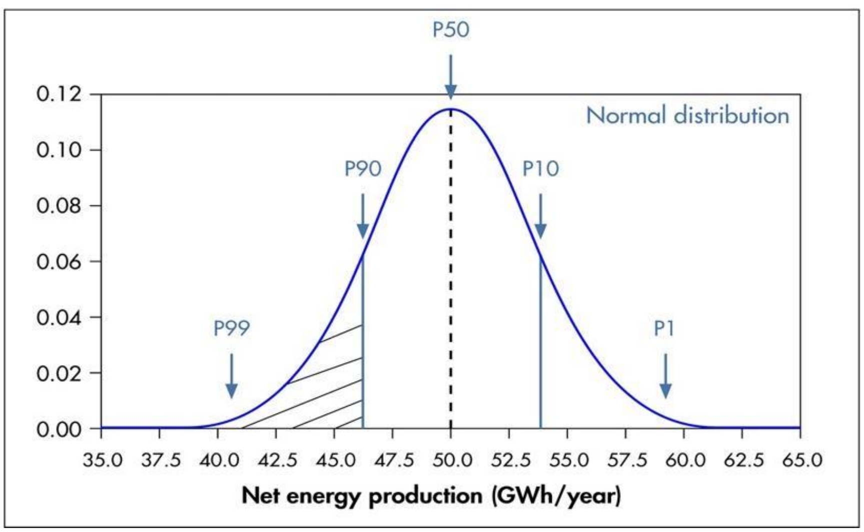


Figure 5: Sample AEP probability distribution.

Source: https://aws-dewi.ul.com/implications-resource-assessment- uncertainty-project-finance/

Lenders and equity investors evaluate every project for risks. Statistical estimations of risk play a vital role in determining how a wind project is financed and at what cost. Mitigating those risks can be accomplished by establishing contingency plans for common negative risk events and by properly pricing that risk into the cost of capital. This is most important for large FTM and BTM projects where institutional debt plays a large role.

To minimize risk, lenders usually size project debt such that it can be serviced even during a low production year. At a Debt Service Coverage Ratio (DSCR) of 1.0 at the P99 level, a lender is nearly guaranteed to have its debt payments covered because such a low revenue year is only predicted to happen 1% of the time. An accurate WRA with low uncertainty leads to higher P99 values, a larger debt offering, and a lower proportion of expensive equity capital in the capital stack. Equity investors, on the other hand use P50 to determine a project's likely rate of return.

Primary Economic Modeling

Once the wind resource has been estimated for a site, the project's potential economic performance can be modeled. For early-stage economic modeling, it is common to start with average cost assumptions for equipment, permitting, balance of station, construction, and operations and maintenance. After adjusting the average costs to reflect any unique local conditions, a developer should perform a sensitivity analysis on the assumed values to better understand which costs most influence the project's financial performance. Extra attention and effort can be applied to refining and reducing those costs. This early modeling step ensures that only those projects with a reasonable chance of positive financial performance are pursued further.

What the experts say…

Any P values can be calculated from a sufficiently long [wind resource] simulation. Note that the P values usually have a time period attached to them, such as 1, 5, 10 or 20 years. This is because the uncertainty of any particular future period depends on both the prediction error (flaws in the model and method) and the interannual variability of the wind resource. The former does not depend on period length, but the latter does, and is largest for the shortest period. So uncertainty is highest and P90 lowest for the 1-year time period.

Mark Stoelinga
ArcVera Renewables

Detailed Design and Engineering

If initial project models suggest a promising financial performance, development may proceed to the detailed design and engineering phase. At this time the development team determines the likely locations of the turbine(s), any necessary access roads, the collection grid, and the interconnection system. The designs at this stage are still influenced by cost assumptions, and the project layout decisions balance the costs and benefits of various designs. For example, siting a turbine further from its interconnection point to harvest a stronger wind resource must justify the added road and interconnection costs such a move would incur.

Engineering campaigns then add crucial data to the detailed design. Soil conditions are investigated at the turbine locations to inform foundation, road, collection system, and interconnection system designs. The developer then estimates foundation and other balance of station costs resulting in a higher-confidence overall project cost estimate.

Secondary Economic Modeling

Secondary economic modeling commences once the refined construction cost estimates are available. Even at this late stage there are opportunities to modify the turbine selection. Changing the choice of turbine impacts the project layout because it introduces a different hub height and rotor size, so it is not uncommon to have a suite of secondary economic models that explore all remaining options. This project development step is often the last go/no-go decision point, and appropriate margins are thus incorporated in the cost estimates to absorb expected near-term price changes.

Project Construction and Installation

Large, FTM distributed wind projects can take months to build, often mirroring the timing and complexity of a utility-scale wind farm. Conversely, small BTM or off-grid projects can be completed in weeks or even days. Experienced developers should schedule each element of the construction process to minimize cost and risk, including exposure to weather-related delays.

Larger FTM projects comprised of multiple large-scale turbines may require access roads, laydown areas, crane pads, and interconnection equipment yards. Foundations for large turbines are typically spread-foot foundations requiring large excavated areas, large amounts of reinforcing steel, and many dozens of cement truckloads. Delivery of large components, such as tower sections and blades, may also necessitate the modification of nearby intersections. Given the potential for impacts to the project site and supply roads, the developer must coordinate with the Authority Having Jurisdiction (AHJ) to ensure that the construction process meets environmental requirements and avoids damaging existing infrastructure.

Smaller projects usually enjoy an abbreviated and simplified construction schedule. Normally, such projects do not require new access roads since the smaller construction and delivery vehicles can utilize existing site roads. Rubber-tired cranes are typically suitable for smaller projects, so even the crane delivery is simpler and less costly and the need for a crane pad is typically eliminated. Foundations for smaller turbines can utilize either spread-foot foundations or pier foundations; in some cases the use of helical piles eliminates the need for foundation concrete entirely. Foundations for small turbines may also be optimized with tensionless piers or fiber-reinforced concrete requiring less reinforcing steel and its associated labor. It is also not uncommon for small turbines to utilize a “typical” foundation that is designed to work under “most” conditions, by being larger than necessary for “many” conditions. This standardizing

Figure 6: Medium-sized wind turbine tower installation.

(Photo courtesy of Charles Newcomb)

practice can reduce foundation design and engineering costs increasing the potential market size for turbines (and developers) using this strategy.

The list of necessary commissioning procedures also scales with turbine size and project complexity. All wind turbines are designed to operate autonomously without the need for human intervention under normal conditions. Large turbines, however, are uniquely value-engineered to deliver energy at the lowest possible cost with operational and mechanical margins minimized to the extent permitted by design and engineering standards. To operate safely within the resulting operational envelope, sophisticated safety systems are incorporated that constantly track the turbine operation. The developer must confirm that the wind turbine's safety and control systems can safely navigate the full range of operational conditions before autonomous operation is permitted. Thus, the commissioning period can be extensive, sometimes lasting many months, while the project waits for the full suite of operational conditions to present themselves.

In contrast, small turbines are typically not value engineered to the same degree, so they have larger operational and safety margins. Their safety systems, therefore, are less complex. For these turbines, the commissioning process can be limited to ensuring that control setpoints and sensor outputs are within normal ranges without the need to witness operations across the full range of expected environmental conditions. This results in very fast commissioning schedules, even just a few hours.

Grid Integration and Interconnection

A large FTM project usually requires its own interconnection equipment yard, like a utility-scale wind farm. Proper distribution system integration requires coordinated design, engineering, testing and operations of the circuit protection and interconnection equipment with the cooperative involved in every step. Electric cooperative engineers should be familiar with this process.

In contrast, smaller BTM projects may not need the installation of new interconnection equipment. Witness testing of the interconnection relay's ability to disable the project in the event of a grid outage may be the only requirement. BTM projects often include a grid protection relay even when the inverter is both capable and certified for interconnection as this has historically reduced the time required for interconnection approval.

Communication with Stakeholders

It is vitally important that the developer engage early and often with both project neighbors and with the community at large. While the actual impacts from wind projects are generally minimal, without proper community engagement the perceptions of impact (and cost to other members) can be viewed through a worst-case lens and considerable effort and cost may be required to bring the perception back in line with reality. The level of appropriate community engagement also depends on the project size and use case. Smaller, off-grid projects likely will warrant little in the way of community engagement while a FTM project generally triggers the engagement of a public planning commission. As the community's trusted energy advisor, the cooperative can ensure that member-owners are informed of the project plan and its progress toward commercial operation. This includes how prospective environmental concerns will be handled as well as how the project's timing, pace, and scale could impact the community throughout construction and operation.

Decommissioning and Repowering

Wind turbines have historically been designed for a 20-year operational life. This does not mean that every component or system on a wind turbine is designed to last 20 years; there are many components that are replaced several times over the life of a wind turbine. Rather, it means that a 20-year period is used for initial project financial modeling and that the main components are not expected to exceed their fatigue limits within 20 years of service.

It is becoming increasingly common to extend project lifecycles beyond their initial operational periods. The effort required to accomplish this ranges from simply certifying that the principal equipment components are safe to run for a few more years, to replacing or refurbishing the major components, to removing and replacing the entire turbine (including the tower and foundation). When a significant portion of the turbine are replaced or refurbished it is called "repowering." This prolongs the amortization schedule for balance of station and development costs.

If a project will not be repowered, there are established standard practices for turbine removal and site reclamation. These include guidance for foundations (typically removed to 3' below grade), interconnection cables (fully removed and recycled), and regrading and reseeding of disturbed area. While there are different approaches for handling the costs of decommissioning, it is generally accepted that unless significant soil works were required (such as a ridge-top road), the recycling or resale value of the equipment is sufficient to cover the cost of site reclamation. Cooperatives can facilitate decommissioning by helping the host determine how decommissioning costs will be covered and by collaborating to determine the site remediation schedule.

Project Design and Development by Use Case

The table below summarizes information on distributed wind project development as it applies to the use cases defined in the RADWIND Use Case Report.[18]

Table 3: Distributed wind project design and development choices differentiated by use case.

	FTM	BTM			Off-Grid
Turbine Size	**Typically Large**	**Large**	**Medium**	**Small**	**Small**
Pre-Construction Development	• Equipment sizing • Rigorous early AEP estimates • Early economic modeling • Detailed design and engineering • Secondary economic modeling	• Equipment sizing • Rigorous early AEP estimates • Early economic modeling • Detailed design and engineering • Secondary economic modeling	• Equipment sizing • AEP estimate • Early economic modeling • Detailed design and engineering • Secondary economic modeling	• Equipment sizing • Basic AEP estimates • Economic modeling	• Equipment sizing • Basic AEP estimates • Economic modeling
Construction and Installation	• Months to complete • Accessory construction (roads, etc.) • Extensive commissioning procedures	• Months to complete • Accessory construction (roads, etc.) • Extensive commissioning procedures	• Months to weeks to complete • Some commissioning procedures	• Weeks or days to complete • Basic commissioning	• Weeks or days to complete • Basic commissioning
Grid Integration and Interconnection	• Usually requires dedicated equipment yard • Coordinated testing and operation of all equipment	• Potential for a dedicated equipment yard • Coordinated testing and operation of all equipment	• Interconnection equipment likely not needed • Witness testing of grid protection relay	• Interconnection equipment likely not needed • Witness testing of grid protection relay	• N/A

[18] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Use-Cases-Report-April-2021.pdf

Communication with Stakeholders	• Early, often, and essential! • Planning commission involvement	• Early, often, and essential!	• Early, often, and essential!	• Early, often, and essential!	• N/A

Project Financing

In the summer of 2021, the RADWIND project published *Financing Distributed Wind Projects in Rural Electric Cooperative Service Areas*,[19] which described types and sources of capital to fund wind projects as well as wind asset ownership and financial structures. In this report, the project team 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. The final sections of this paper outline some provisions in the Inflation Reduction Act of 2022 that impact distributed wind financing and point the reader to RADWIND case studies that show various distributed wind financial and ownership structures in action.

Costs

The costs incurred while screening, developing, operating, and decommissioning (or repowering) a distributed wind asset vary based on the turbine size and on local economic conditions. Additionally, advancements in technology have driven the overall costs of wind energy steadily downward. Thus, the of-the-moment cost of a wind project is challenging to state with confidence, but researchers and developers are working together to understand and quantify these costs for interested parties. The information in this section is meant to inform cooperatives and member-owners on the range of costs a distributed wind developer may present to co-op leadership.

Table 4 contains cost data drawn from the National Renewable Energy Laboratory's *2020 Cost of Wind Energy Review*.[20] Cost category labels come from this report, but costs may be organized differently by individual developers. Additionally, NREL utilizes hypothetical "reference projects" with attributes that represent national trends. While the medium and small turbines are priced as standalone installations, the large turbine (2.8 MW rated capacity) is priced as though it were part of a 73-turbine wind farm. The costs associated with a turbine in such a project will differ from those for a turbine in a 1-10 turbine installation more typical of distributed wind.

[19] https://www.cooperative.com/programs-services/bts/radwind/documents/radwind-finance-methods-report-august-2021.pdf

[20] https://www.nrel.gov/docs/fy22osti/81209.pdf

Table 4: Categorized approximate costs for large, medium*, and small wind turbines installed in the U.S. (2020$).
Adapted from (Stehly & Duffy, 2021)

Cost Category		FTM/Large BTM (2.8 MW)	Medium* BTM (100 kW)	Small BTM/Off-Grid (20 kW)
Turbine	**Rotor**	$1,021/kW (Comprises 46.8% of LCOE)	$2,530/kW (Comprises 51.5% of LCOE)	$2,575/kW (Comprises 41.3% of LCOE)
	Nacelle			
	Tower			
Balance of System / Balance of Station	**Foundation**	$319/kW (14.6% of LCOE)	$1,770/kW (36.0% of LCOE)	$3,100/kW (49.7% of LCOE)
	Site Access and Staging			
	Electrical Infrastructure			
	Assembly and Installation			
	Development			
	Engineering and Project Management			
Financial	**Contingency**	$122/kW (5.0% of LCOE)	N/A	N/A
	Construction Finance			
Total Capital Expenditures (CapEX)		$1,462/kW	$4,300/kW	$5,675/kW
Operations & Maintenance (OpEX)		$35/kW/yr. (9.0% of LCOE)	$35/kW/yr. (12.4% of LCOE)	$43/kW/yr. (33.6% of LCOE)
Total LCOE		$34/MWh	$99/MWh	$151/MWh

***The 100 kW reference turbine from this source falls just outside the defined “medium-sized” range of 101 – 999 kW.**

Taken together, these cost data inform a cooperative on the range of costs to expect when a developer or installer submits a proposal. The following figure combines data from four wind energy market reports to show the average installed costs (or CapEX) for wind projects of increasing size over time. As the graph shows, per-kW installed costs have decreased since 2015, and they also decrease as the project size increases. At the same time, the range of installed costs narrows as the project gets larger. Costs for very small wind turbine installations (those with turbines less than 100 kW in rated capacity) are most sensitive to local economic conditions, and so the range of potential installed costs is large.

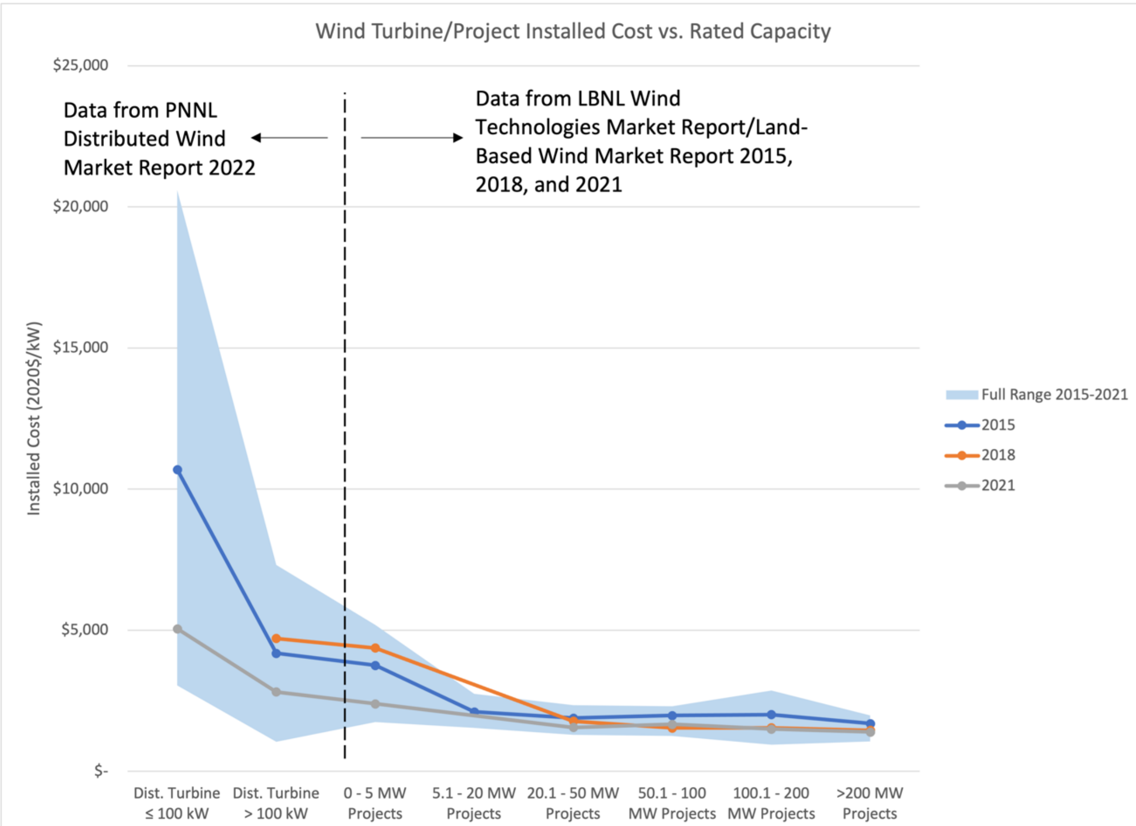


Figure 7: Wind turbine and wind energy project installed costs over time by rated capacity.
Adapted from (Wiser & Bolinger, 2015, 2018, 2021) and (Orrell et al., 2022)

Cash Flow for Cooperatives and Member-Owners

Previous publications in the RADWIND library introduced the use, value, and business cases for distributed wind in rural electric cooperative service areas. "Value" is often construed to have a solely monetary significance, but as the RADWIND Value Case Report[21] explains, many costs and benefits of a distributed wind project are challenging to quantify. For this reason, "value stream" is defined as a cost or benefit experienced from a particular stakeholder perspective regardless of economic value. These value streams can vary by region and market, and the ability to realize the value streams may depend on

[21] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Value-Case-Report-May-2021.pdf

anticipated technological advances, market developments, and policy initiatives. Furthermore, a distributed wind project's value can vary depending on its capacity and location.

The most informative method of assessing a distributed wind project's value—or the value of any distributed energy resource—is to "stack" all the value streams that project provides to the various stakeholders. Distributed wind, with good siting and wise technological design, can do more than offset the most expensive, marginal electricity purchased by a cooperative, so a direct comparison of the wind energy cost to the average wholesale energy cost does not provide a complete picture. Quantifying future incremental cash flows when a distributed wind project begins operation and combining them is more accurate. Additionally, "intangible" benefits like those discussed in the Value Case and Business Case Reports can add significant value that should be considered.

Here, common quantifiable value streams are converted to cash flow descriptions. Figure 8 identifies the revenues and expenses for interconnected entities when a distributed wind project begins generating electricity for the distribution grid. For the most part, elements in these figures can apply to both FTM and BTM installations.

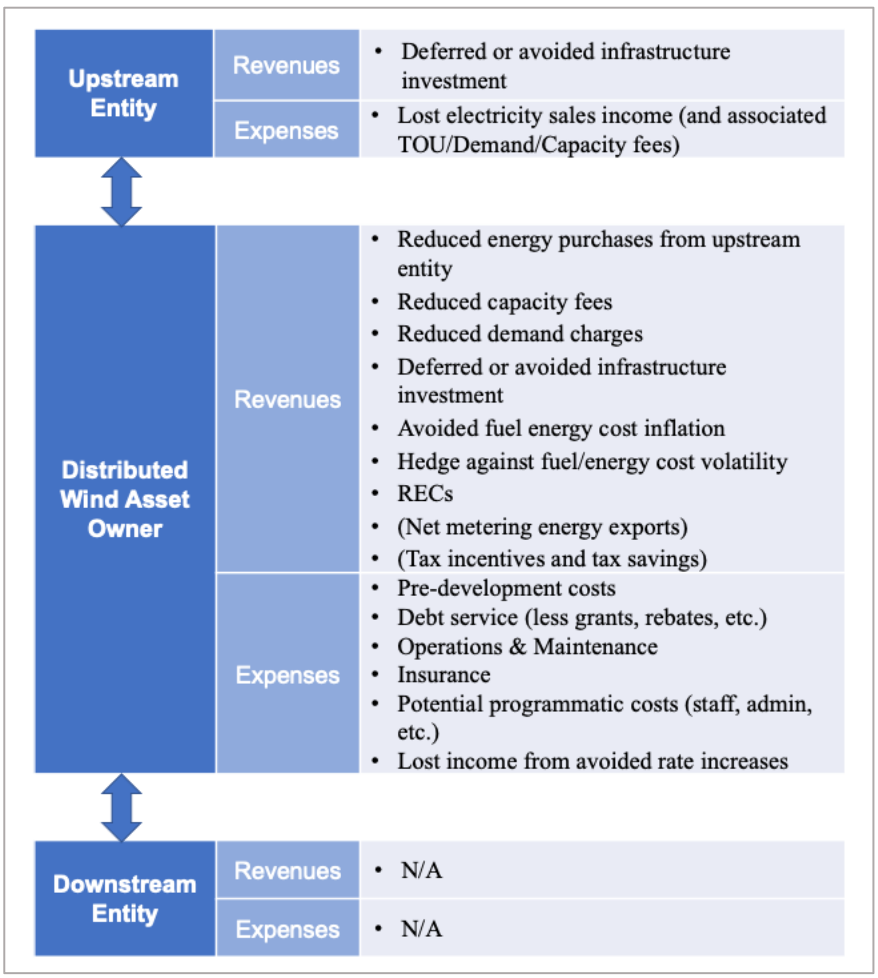


Figure 8a: Revenues and expenses for interconnected entities when a distributed wind asset is owned by a cooperative

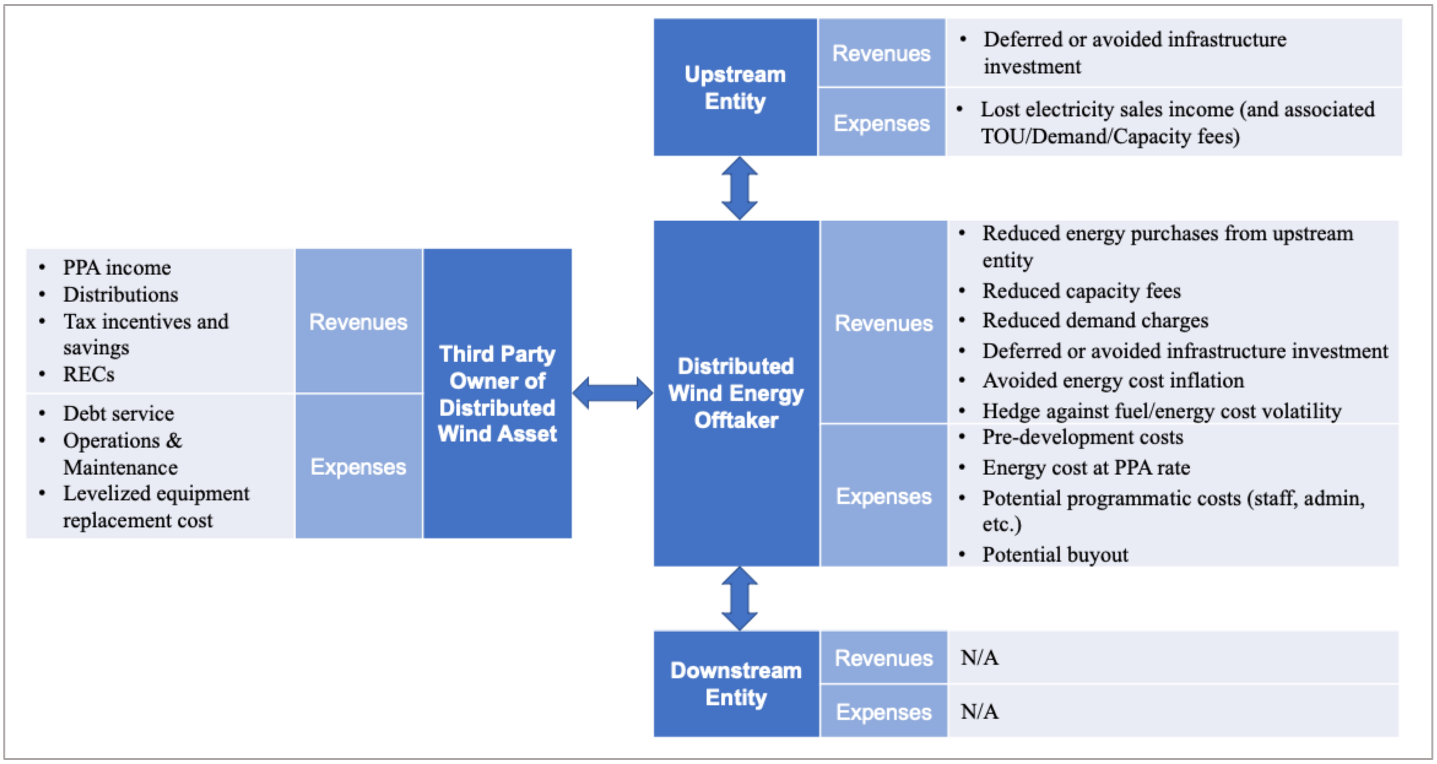


Figure 8b: Revenues and expenses for interconnected entities when a distributed wind asset is owned by a third party

Energy-as-a-Service business models (see Section 8.2 of the RADWIND Business Case Report)[22] would create cash flows that differ slightly from those in the diagrams. For example, a distribution cooperative may elect to own and manage a distributed wind asset on a member-owner's property and charge a flat fee that covers both the energy management service and the member-owner's electricity. In that case, the host would see the expense of a monthly utility bill replaced with a subscription fee while they could count "revenue" as the avoided utility bill costs.

If a cooperative plans to buy distributed wind energy from a third-party owner, one of the most crucial financial model inputs is the power purchase agreement (PPA) contract price. Figure 9 shows how wind energy PPA prices have changed over the last ten years. The projects represented here range in size from 1 to 28 MW which covers all FTM distributed wind installations currently operating in cooperative territories. From 2015 to 2021, PPA prices tracked closely with the declining price of natural gas.

[22] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Report-Business-Case-April-2022.pdf

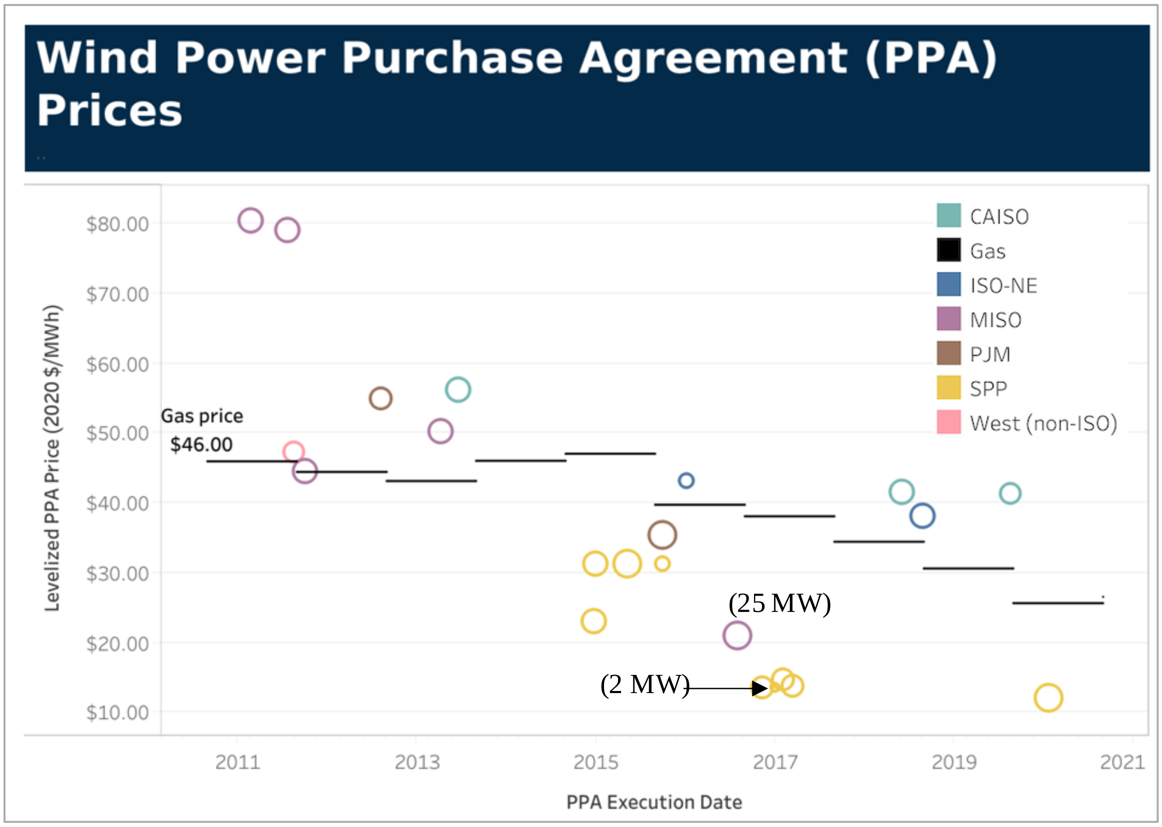


Figure 9: Nationwide wind energy PPA prices for projects 1-28 MW in rated capacity, 2011-2021. Circle size denotes project capacity. (Wiser & Bolinger, 2021)

Financing Distributed Wind Projects

The RADWIND Finance Report[23] was published prior to the passage of the Inflation Reduction Act of 2022. While most concepts in the report still hold true, the new bill makes significant changes to the tax credits that have historically benefited renewable energy development. In addition, the IRA introduces new sources of capital and new funding for policy initiatives that will impact distributed wind development.

In short, the law re-establishes the Production Tax Credit (PTC) and Investment Tax Credit (ITC) for wind projects until the end of 2024 at which point the two tax credits will be replaced with a "technology-neutral" ITC and PTC for non-greenhouse gas emitting technologies. Both tax credits offer base tax credit rates that can be enhanced by fulfilling various criteria for wages and employment, domestic sourcing of materials and manufactured goods, development in an "energy community," and/or development in a low-income residential project. Starting in 2023, the ITC covers energy storage facilities—both standalone and those associated with a generation facility—as well as some

[23] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Finance-Methods-Report-August-2021.pdf

interconnection properties. Most importantly, the IRA includes the provision of a "direct pay" option. Starting in 2023, this will allow tax-exempt entities, including electric cooperatives, to receive the value of the federal PTC and ITC as direct payments. In the past, co-ops had no direct way to access the tax incentives unless they established a taxable subsidiary. Direct pay changes that, and it has a potentially large impact on asset ownership structures.[24]

Project Financing by Use Case

The table below summarizes information on financing distributed wind projects as it applies to the use cases defined in the RADWIND Use Case Report.[25] While these data represent typical arrangements, many cooperatives and their member-owners have found innovative ways to finance their projects. As government and private institutions initiate financing mechanisms in the Inflation Reduction Act, some of the information in Table 5 may change.

Table 5: Distributed wind project financing considerations differentiated by use case.

	FTM	BTM			Off-Grid
Turbine Size	**Typically Large**	**Large**	**Medium**	**Small**	**Small**
Typical Ownership Structures	• Third-party owned (TPO) • G&T owned • Partial or delayed co-op ownership • Co-op owned	• Member-owned • TPO • Co-op owned • G&T Owned	• Member-owned • TPO • Co-op owned	• Member-owned	• Member-owned
Capital Sources	• Debt: USDA loans; private banks • Equity: Tax equity investors; sponsor equity • USDA grants	• Debt: USDA loans; private banks • Equity: Tax equity investors; sponsor equity • USDA grants	• Debt: USDA loans; private banks • On-bill financing or tariffs	• Debt: USDA loans; private banks • On-bill financing or tariffs	• Debt: USDA loans; private banks • On-bill financing or tariffs

[24] As of January 2023, the provisions of the IRA are undergoing regulatory review to determine how they will be applied by the U.S. Treasury's Internal Revenue Service. For more information on this process or on specific provisions of the IRA, contact information for NRECA Government Relations staff can be found here: https://www.cooperative.com/programs-services/government-relations/Pages/Legislative%20Issues/Inflation-Reduction-Act-of-2022-fact-sheet.aspx.

[25] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Use-Cases-Report-April-2021.pdf

Federal Tax Incentives	• PTC • ITC • MACRS	• PTC • ITC • MACRS	• ITC • MACRS	• Residential ITC • MACRS	• Residential ITC • MACRS

Finance and Business Case Studies

The RADWIND project has produced a series of case studies[26] which highlight both time-tested and novel financing methods. The list below is a good starting point to learn more about distributed wind finance from the perspective of distribution cooperatives.

PPA with Third-Party Owners:

Lake Region Electric Cooperative, MN[27]

Cuming County Public Power District, NE[28]

San Isabel Electric Association, CO[29]

Direct Cooperative Ownership:

Rural Electric Convenience Cooperative, IL[30]

Iowa Lakes Electric Cooperative, IA[31]

Kotzebue Electric Association, AK[32]

Tax Equity Partnership Flip and a Cooperative-Owned Taxable Subsidiary:

Fox Islands Electric Cooperative, ME[33]

[26] https://www.cooperative.com/programs-services/bts/radwind/Pages/RADWIND-Case-Studies.aspx

[27] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-Lake-Region-May-2021.pdf

[28] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-CCPPD-July-2021.pdf

[29] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-San-Isabel-Nov-2021.pdf

[30] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-RECC-May-2021.pdf

[31] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Iowa-Lakes-Case-Study-March-2021.pdf

[32] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-Kotzebue-Nov-2021.pdf

[33] https://www.cooperative.com/programs-services/bts/radwind/Documents/RADWIND-Case-Study-Fox-Islands-July-2021.pdf

Behind-the-Meter Distributed Wind:

See Section 6.2.1 of the RADWIND Business Case Report[34] for specifics on:

Honda Transmission plant, OH
Anheuser Busch plant, CA
REG ethanol plant, MN

Small Residential BTM Turbine, OK (Oklahoma Electric Cooperative)[35]

Medium-Scale BTM for Commercial Agriculture, CO (Y-W Electric Association, Inc.)[36]

On-Bill Financing/Tariffed On-Bill:

Opportunities for Including Distributed Wind in On-Bill Programs[37]

[34] https://www.cooperative.com/programs-services/bts/radwind/Documents/Advisory-RADWIND-Finance-Case-Study-OBF-Sept-2022.pdf

[35] https://www.cooperative.com/programs-services/bts/radwind/Pages/Long-Term-Savings-with-Distributed-Wind.aspx

[36] https://www.cooperative.com/programs-services/bts/radwind/Pages/Member-Financed-Distributed-Wind.aspx

[37] https://www.cooperative.com/programs-services/bts/radwind/Documents/Advisory-RADWIND-Finance-Case-Study-OBF-Sept-2022.pdf

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Appendix A: List of Acronyms

AEP	Annual Energy Production
AHJ	Authority Having Jurisdiction
BESS	Battery Energy Storage System
BTM	Behind-the-Meter
CapEX	Capital Expenditures
CFD	Computational Fluid Dynamics
DER	Distributed Energy Resource
DOD	U.S. Department of Defense
DSCR	Debt Service Coverage Ratio
DW	Distributed Wind
EaaS	Energy-as-a-Service
FAA	Federal Aviation Administration
FTM	Front-of-the-Meter
FWS	U.S. Fish and Wildlife Service
G&T	Generation and Transmission
GW	gigawatt
IPaC	Information for Planning and Consultation
IRA	Inflation Reduction Act of 2022
IRS	Internal Revenue Service
ITC	Investment Tax Credit
kW	kilowatt
LCOE	Levelized Cost of Energy
LMI	Low- to Moderate-Income
MACRS	Modified Accelerated Cost Recovery System
MCP	Measure-Correlate-Predict
MW	megawatt
NEPA	National Environmental Policy Act
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
NWP	Numerical Weather Prediction
O&M	Operations and Maintenance
OpEX	Operations and Maintenance Expenditures
PNNL	Pacific Northwest National Laboratory
PPA	Power Purchase Agreement
PTC	Production Tax Credit
RADWIND	Rural Area Distributed Wind Integration Network Development

REC	Renewable Energy Certificate
RFP	Request for Proposal
TPO	Third-Party Owner
USDA	United Stated Department of Agriculture
VMM	Virtual Meteorological Masts
WEG	Wind Energy Guidelines
WRA	Wind Resource Assessment

Appendix B: Further Wind Resource Characterization

For certain projects where on-site measurements have been collected, the developer may need to ensure that net energy production will result in sufficient revenue or cost savings to meet debt service obligations, even during the lowest expected wind resource years. The developer should, therefore, take three additional factors into account that add nuance to the average wind speed and its distribution: the directional nature of the local wind resource; the seasonal variation in wind resource; and the historical context for the wind resource as measured at the site.

Each wind direction sector may have unique ground cover conditions, topography, and slope that affect the wind turbine's ability to convert the wind's energy into electrical energy. By coordinating direction and terrain data, developers can create an *energy wind rose* that visually demonstrates when and from what direction energy-producing wind blows (Figure 2). This information is used to properly site a single turbine with respect to on-site obstructions or to orient multiple turbines with respect to each other. All turbines automatically turn, or "yaw," to face the wind, so it is not necessary to install the turbine such that it points a specific direction. Turbines do need to "unwind" after making a set number of complete revolutions around the tower. This unwinding is automatically triggered, and it is initiated when the turbine has detected that there is insufficient wind to generate power.

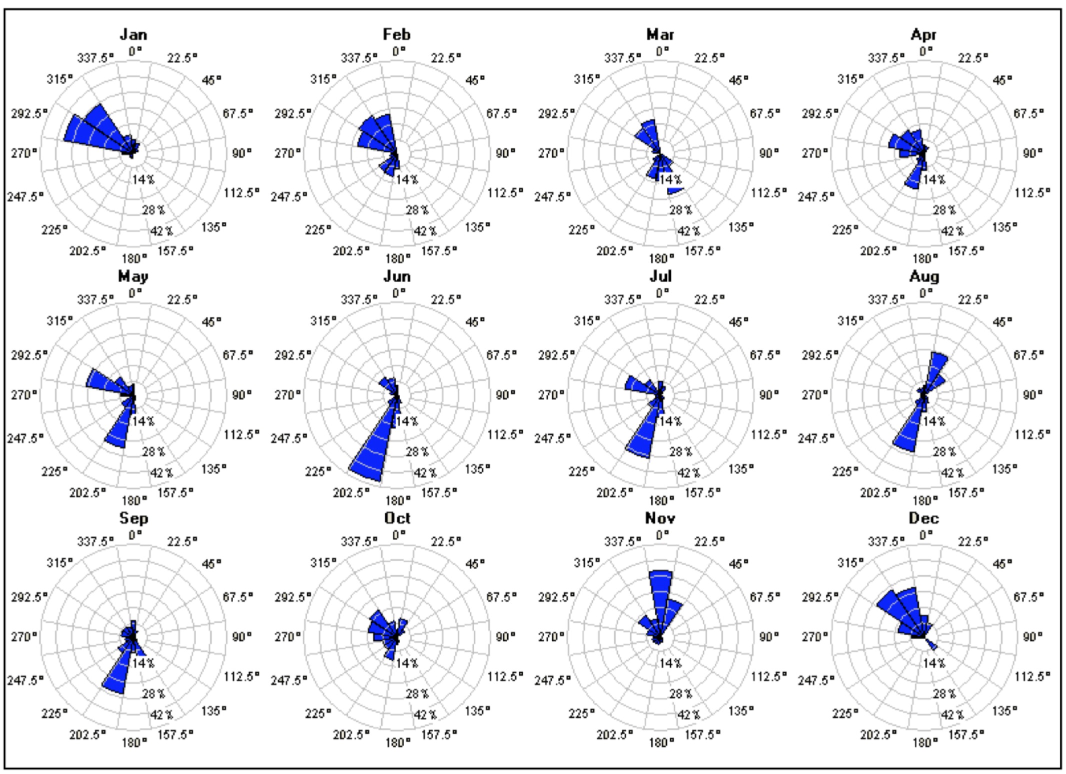

Figure 3: Monthly energy wind rose for a naval station in Rhode Island showing direction and generating potential of wind throughout the year.
(Robichaud et al., 2012)

Developers evaluate the seasonality of the wind resource to understand the quantity of energy that is likely to be produced at different times of the year. This is of unique importance for cooperatives and other utilities with seasonal tariffs. The typical North American wind pattern is characterized by stronger winds in the winter and lighter winds in the summer (see Figure 3 as an example). This means that a non-hybrid[38] wind project can be expected to produce more energy in the winter than in the summer. Developers promoting and developing projects in these cases should be expected to clearly reflect the seasonality of production in their financial models.

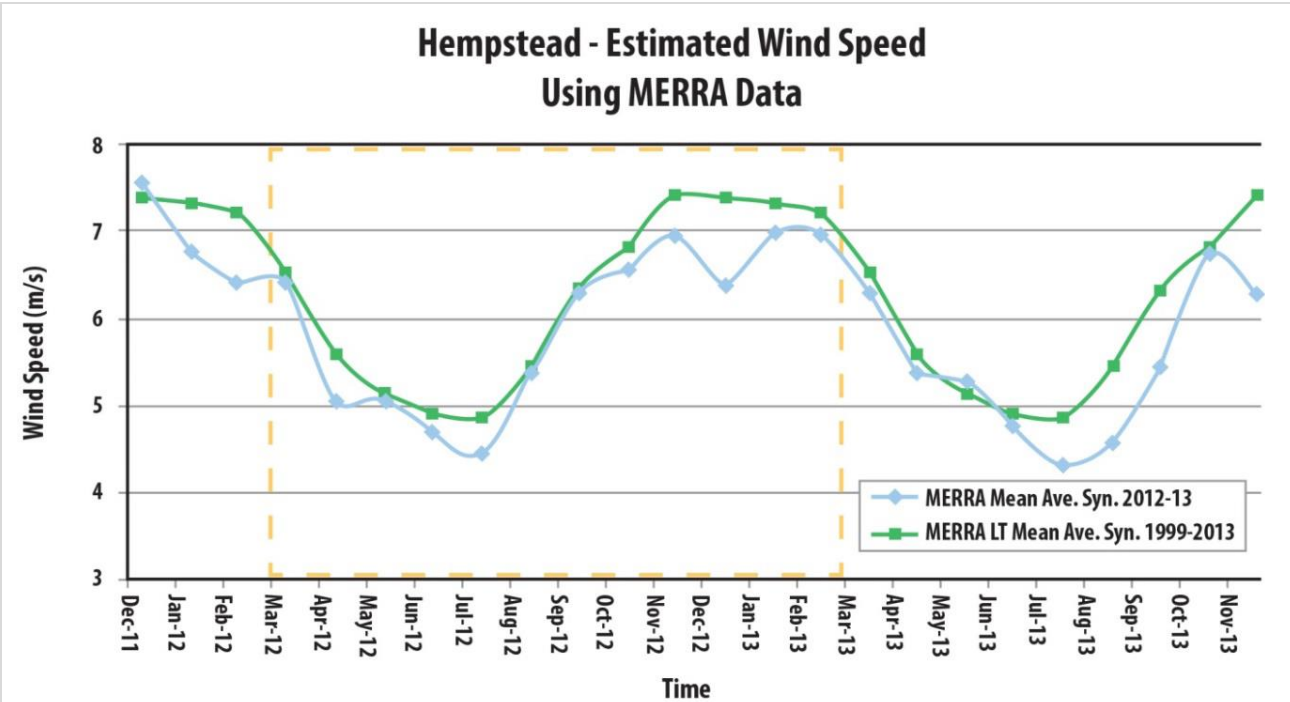

Figure 4: Seasonal variation in wind speed at a potential 100 kW wind turbine project site in Hempstead, NY. Dashed yellow lines enclose one year of data. (Olsen & Preus, 2015)

Developers could also acquire information to assess the project's wind speed estimates regarding the wind resource's historic inter-annual variability and the uncertainties of the modeling efforts themselves. Projects that have taken on-site measurements to secure financing conduct this additional analysis to put the measurements in context of local historical weather conditions. This step, known as Measure-Correlate-Predict or MCP, uses nearby, long-term measurements to provide comparative data. This is done by establishing the statistical relation between site-specific short-term wind data (**M**easure) and long-term reference wind data from nearby sites using the concurrent or overlapping data period (**C**orrelate), and then implementing the relation to the entire long-term data period (**P**redict) (Zhang, 2015).

[38] Wind and solar patterns are complementary across much of the country. A hybrid project combining wind and solar technologies can help capture higher wind production in the winter and higher solar production during the summer for more even production across the year. For more information on this topic, see https://www.cooperative.com/programs-services/bts/radwind/Documents/Advisory-RADWIND-NREL-Wind-Solar-Complementarity-June-2022.pdf/

Advancements in wind resource modeling allow the nearby measurements, which may not have been taken at the same tower height or at an area with identical surface conditions, to be adjusted to match the proposed project's parameters.

What the experts say…

[Regarding accuracy over very long timespans]: This depends on how long the mesoscale model simulation is. The same rules apply about historical climate uncertainty to mesoscale model simulations as they do to on-site observations of short duration. The longer the simulation, the lower the historical climate uncertainty.

- Mark Stoelinga

Appendix C: Method of Bins Example

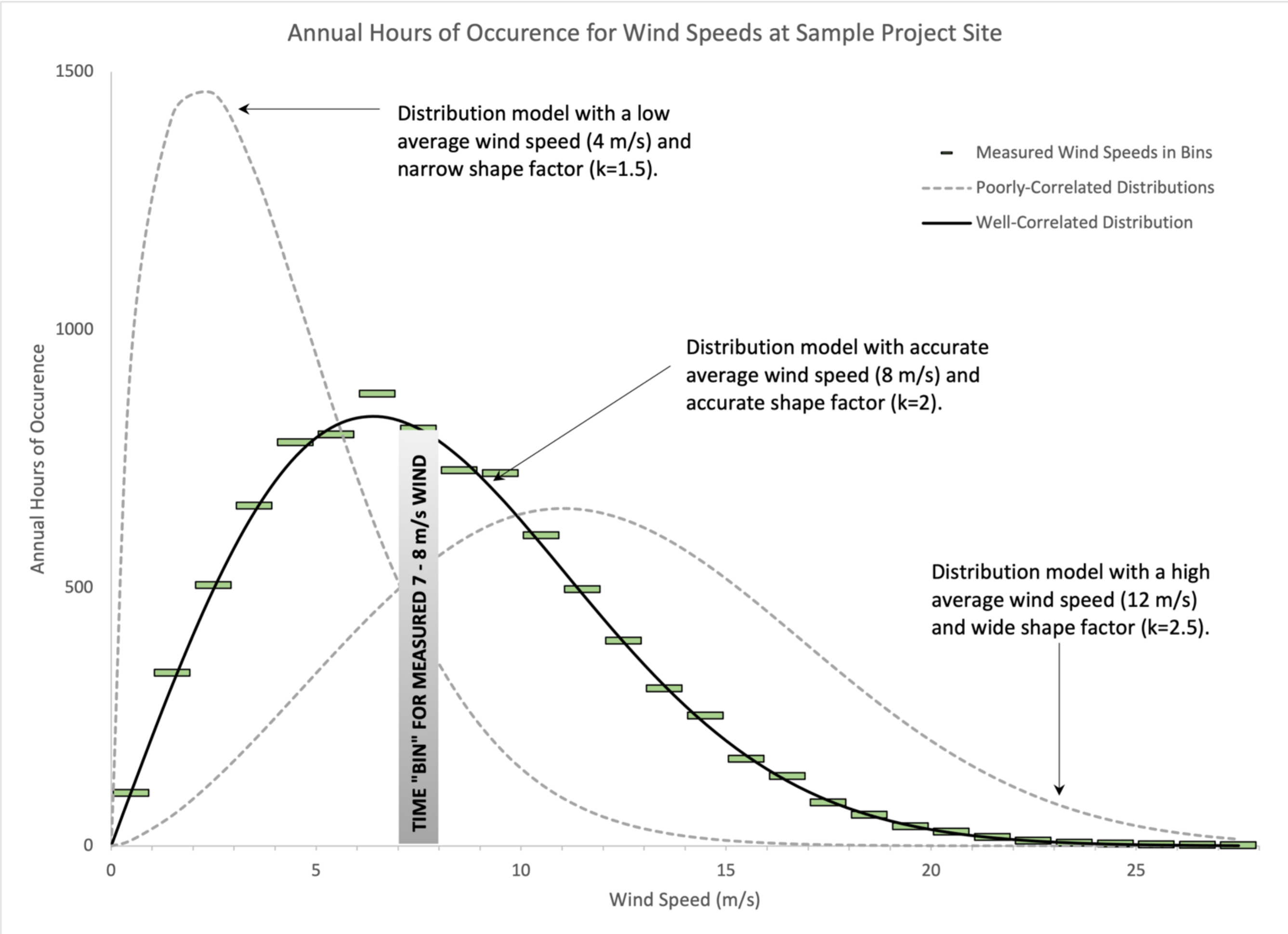

Figure B1: Wind speed distribution example for a future distributed wind turbine site showing curves with different average wind speeds and shape factors.

In this example, mesoscale wind data from a potential 2.8 MW wind turbine site is examined for generation potential. "Method of bins" refers to a technique where any time interval with measured wind speed between integer values is added to the "bin" for that range. For example, a 10 min time interval where the wind speed was 7.2 m/s would be added to the bin for 7-8 m/s wind speeds.

The average wind speed from a mesoscale model is accompanied by a "shape factor" or "k value," which is a number that describes how wind speeds are expected to range around the average for a given location (Figure B1). As this shape factor increases, the range of possible wind speeds also increases while the distribution shape flattens. Together, the average wind speed and shape factor create a Weibull distribution[39] that closely matches the distribution of wind speeds measured at the site.

[39] A Weibull distribution is a continuous probability curve with shape and scale parameters. These parameters can be varied to create distributions of probabilities that closely match natural phenomena.

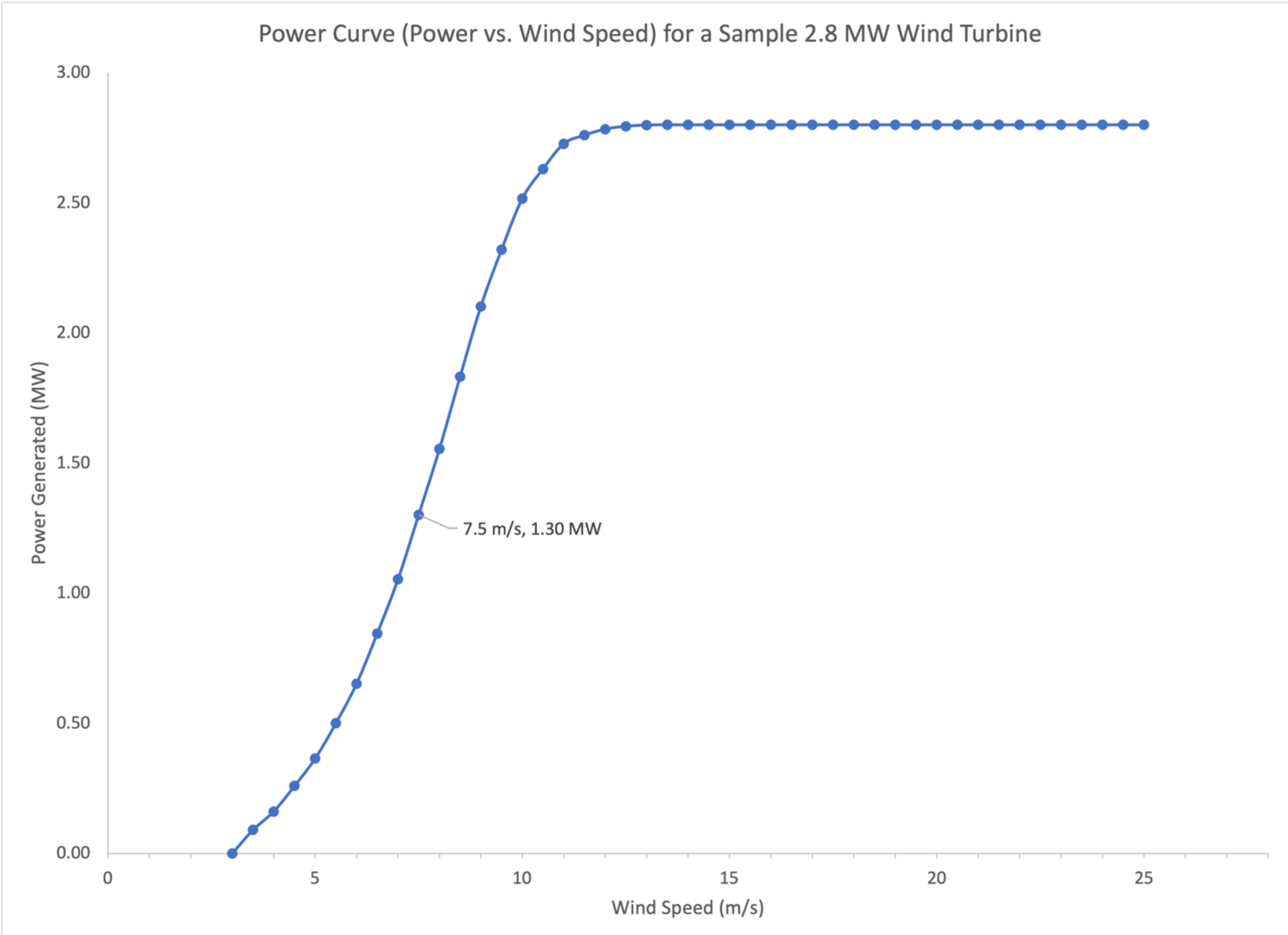

Figure B2: Generic 2.8 MW wind turbine power curve.

The wind speed distribution alone is insufficient to estimate the annual energy production because different turbines will generate different amounts of power within each wind speed bin. The wind speed distribution profile must be reconciled with the 2.8 MW turbine's *power curve*, or ability to generate power over a range of wind speeds. As Figure B2 shows, the turbine "cuts in" (starts generating electricity) when the wind reaches 3 m/s and "cuts out" at 25 m/s to avoid damaging the machinery. At a wind speed of 7.5 m/s, the turbine is expected to generate about 1.30 MW of power (note the labeled point on the graph).

When the hours within a specific wind speed bin are multiplied by the turbine's average power for the same wind speed bin, an interested party can estimate the quantity of energy produced annually from that specific wind speed bin:

$$[bin\ time\ from\ Weibull\ distribution\ (hr)] \times [power\ generated\ at\ bin\ wind\ speed\ (MW)] =$$

$$809\ hr \times 1.30\ MW = 1{,}052\ MWh$$

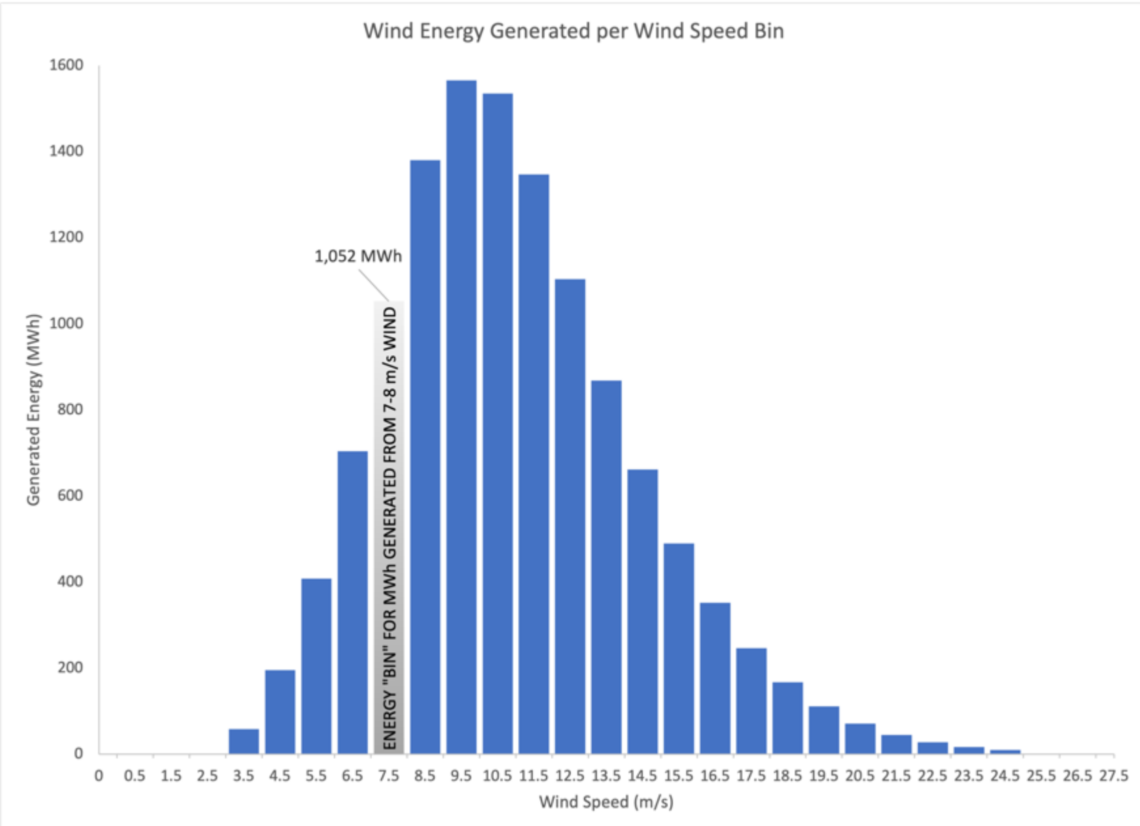

Figure B3: Wind energy generation estimates for each wind speed "bin" at the proposed site.

When the process is repeated for each wind speed bin and the products of power and time for all bins are summed together, the estimated Gross AEP results: **12,410 MWh or ~12.4 GWh annually**.

Based on these assumptions a developer can estimate the turbine's *capacity factor*, or percent of maximum annual generation.

$$\frac{Energy\ generated\ (est.)}{Maximum\ possible\ annual\ generation} = \frac{12{,}410\ MWh}{2.8\ MW \times 8{,}760\ hr} = 50.6\%$$