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Value Case for Distributed Wind in Rural Electric Cooperative Service Areas

NRECA

America's Electric Cooperatives

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RADWIND PROJECT REPORT SERIES: Value Case for Distributed Wind in Rural Electric Cooperative Service Areas

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Prepared By:

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Background: The RADWIND Project

NRECA Research's Rural Area Distributed Wind Integration Network Development (RADWIND) project seeks to understand, address, and reduce the technical risks and market barriers to distributed wind adoption by rural utilities. 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 distributed energy resources (DER). For more information on the project and additional resources, please visit the project landing page at www.cooperative.com/radwind.

This is the second in a series of NRECA Research RADWIND reports about wind as a DER. This report describes the characteristics and features of distributed wind and the value streams applicable to distributed wind in different use cases. The first report in this series, *Use Cases for Distributed Wind in Rural Electric Cooperative Service Areas*, explains the primary ways that wind energy technologies can be deployed in electric cooperative service territories as a DER. The next report in this series will discuss the business case for distributed wind.

What Is Distributed Wind?

Distributed wind projects can use any scale of turbine from small kilowatt-scale units up to large multi-MW units, as long as they are connected at the distribution level of the electric grid. As presented in *Use Cases for Distributed Wind in Rural Electric Cooperative Service Areas*, turbines may be connected on the customer side of the meter to serve a local load (i.e., the behind-the-meter use case), directly to the distribution grid as a utility generating asset (i.e., the front-of-meter use case), or directly powering an off-grid load (i.e., the off-grid use case).

Distributed wind is, therefore, differentiated from wholesale power that is generated at large wind farms and carried over transmission lines to substations for distribution to distant end users. Distributed wind projects can be deployed as standalone distributed generation projects or in combination with other DER as hybrid power plants.

Image 1: Cuming County Public Power District purchases electricity from this 2.5 MW GE wind turbine with an 89-meter hub height and a 127-meter rotor diameter.
Photo credit: Boyd Jones

What Is Value?

Valuation is "the process of determining the relative worth, utility, or importance (i.e., value) of options or alternatives to allow their comparison in ways that are clear, transparent, and repeatable" (Markel et al. 2019). Levelized cost of energy (LCOE) and benefit-cost analysis are most commonly used to approximate and compare the value of different energy resources. However, valuation can also include costs and benefits that are difficult to quantify or monetize, including locational and temporal impacts, reliability, resilience, flexibility, sustainability, security, environmental quality, public health and safety, and economic impact.

We use the term 'value stream' to refer to these costs or benefits experienced by the stakeholder. A value stream can, therefore, be positive or negative. The net value is the combination, or the "stacking," of the value streams.

The value of a distributed wind project varies based on the specific technology, capacity, and location of the project. Valuation is also affected if the distributed wind is part of a hybrid power plant with other DER. Value streams of distributed wind can range from bulk energy services to customer-focused benefits, such as outage mitigation and savings on electricity bills. Project value also varies based on perspective; an electric cooperative will have a different perspective on what is valuable to it than a consumer-member.[1] Sometimes utilities, developers, or both are also interested in the value of a project to society as a whole.

This paper identifies characteristics of distributed wind, factors that can influence value, and qualitatively describes the value streams relevant to distributed wind.

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[1] A consumer-member can also be referred to as a member-owner.

Characteristics of Distributed Wind

Some potentially valuable characteristics of distributed wind, particularly when compared with or in relation to other renewable DER technologies, include the following:

- **Generation Profile**

  Wind speeds can be higher in the evenings, at night, and during winter months. This advantage can allow distributed wind to supply energy during certain peak periods, such as the winter heating season in cold climates or summer evenings in warm climates.

- **Complementary with Solar**

  Distributed wind's generation profile tends to be complementary (i.e., negatively correlated) to solar PV generation because solar generation only happens during the day and typically peaks in midday. Solar production is also higher in the summer months while wind can be higher in the winter months (see Image 2 below). This complementarity from resource diversity can allow a wind-solar hybrid to achieve a more consistent renewable generation profile throughout the year. For example, Reiman et al. has demonstrated that distributed wind has the potential to improve resource diversity and resilience in some high-DER grid systems (Reiman et al. 2020).

- **Small Footprint**

  Wind turbines have a smaller footprint than ground-mounted solar PV arrays.[2] This could result in lower land leasing rates for a developer to pay. The small footprint may also be important where land area is expensive or otherwise valuable, and a source of revenue, such as in farming and ranching areas. Crops can be co-located with wind turbines right up to the edge of the turbine's foundation.

- **High Visibility**

  A distributed wind owner or buyer may find value in highlighting their commitment to renewable energy, in which case distributed wind is preferable to other resources because it is highly visible and makes a clear statement.

- **Suitability in Windy Areas**

  For those areas with strong and consistent wind resources, wind can be more cost (and land use) effective than solar PV and other DER. For example, a small farm in Iowa may need 120 kW of solar PV to match the output of a 50 kW wind turbine, while also needing to find the land or rooftop space for that amount of the solar PV.

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[2] The footprint of a 1 MW wind turbine foundation is roughly 2,000 square feet (Berndt 2004) while the siting rule of thumb for ground-mounted solar PV is that 6 acres (261,360 square feet) are needed for 1 MW.

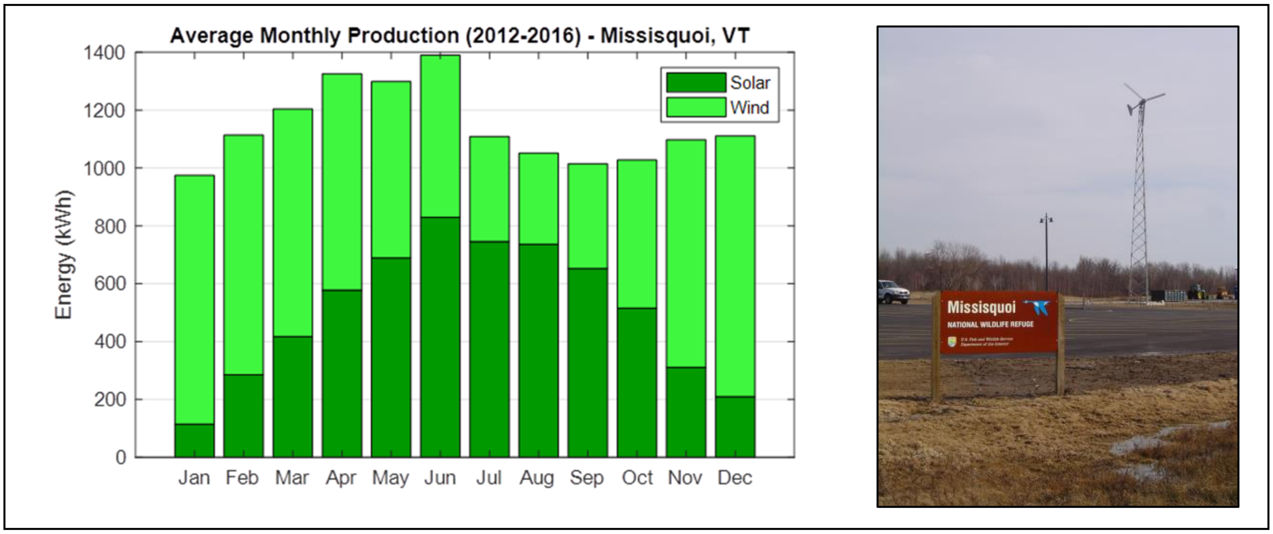

Image 2: The 10-kW wind turbine and 15-kW solar PV array at Missisquoi National Wildlife Refuge (serviced by Vermont Electric Cooperative) demonstrate wind generation's complementary value to solar PV generation on a monthly basis.
Photo credit: Bergey WindPower; Data Credit: Ken Sturm, Missisquoi National Wildlife Refuge Manager

Factors That Influence Value

While not value streams in and of themselves, some factors can have a significant influence of the value of distributed wind. These include wind resource, market structure, tariffs, incentives and mandates, and ownership models.

Wind Resource

A favorable wind resource greatly affects the potential value distributed wind can offer to a cooperative or project owner because higher wind speeds will result in greater energy generation. Because a wind resource is highly site specific, and distributed wind projects are typically sized to serve particular loads or designed with distribution feeder characteristics in mind, evaluating the wind resource and siting considerations is critical.

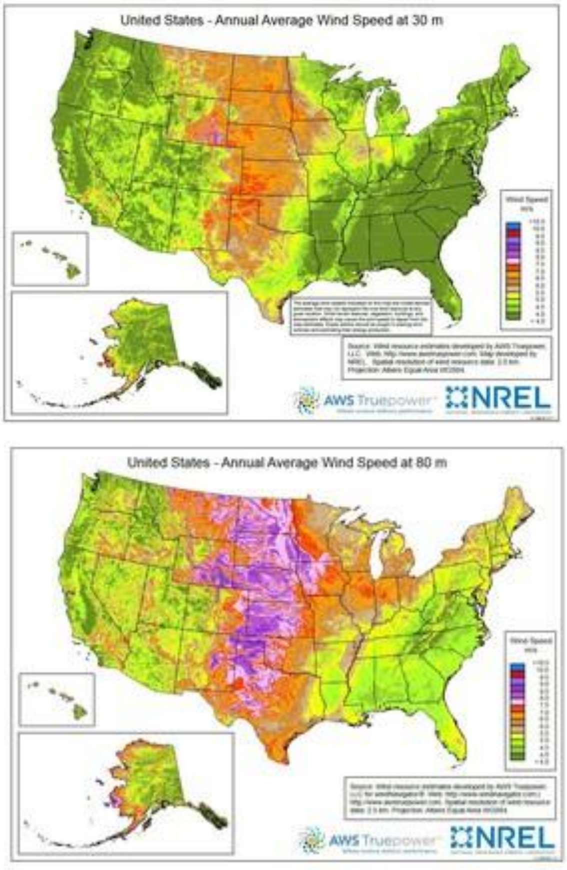

Image 3: Wind resource maps available through the U.S. Department of Energy (DOE 2021a).

Beyond the initial wind resource screening, it is important to understand the seasonal and daily patterns of the potential project's wind resource, especially if the wind turbines will be part of a hybrid power plant with energy storage or another DER, as this will affect the value of the energy generated and stored.

Assessing the wind resource is the essential first step in evaluating the economic feasibility of a potential distributed wind project. For the purposes of an initial screening, cooperatives can target the use of free or low-cost wind resource maps and other publicly available sources for a high-level wind resource assessment.[3] As rules of thumb, a minimum annual average wind speed of 10 to 12 miles per hour (4.5 to 5.4 meters per second) at 30-meter heights (DWEA 2021) and 14.5 miles per hour (6.5 meters per second) at 80-meter heights are recommended as the minimum required to warrant further exploration (DOE 2021a). Free nationwide wind resource maps for 30- and 80-meter heights are available from the U.S. Department of Energy, as shown in Image 3 (DOE 2021a).

Small wind turbines (i.e., those sized 100 kW or less) should reference wind speeds at 30-meter heights since that resource is within close range of typical hub

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[3] Other publicly available wind resource data sources can come from weather stations for agricultural agencies, such as the California Irrigation Management Information System, and airports. However, the measurements at these types of weather stations are taken at low heights close to the ground surface and should therefore only be used to gauge general wind conditions or complement other wind data sources.

heights for those technologies. Large wind turbines (i.e., those sized greater than 1 MW) should reference wind speeds at 80-meter heights. Midsize turbines (i.e., those between 101 kW and 1 MW in size) should default to the reference wind speed at the height closest to their hub height.

Market Structure

Market structure influences which electricity products and services can be bought and sold in which markets. A distributed wind project may have the potential to sell additional services if the project is in an area with markets for these services. Selling these services can generate additional revenue streams for the project. Different markets have different products, so it is important to consider the potential products that may be available in a specific area of interest. A hybrid power plant combining multiple technologies (e.g., wind with solar and/or battery storage) may be able to provide more services to the market than wind alone.

FERC Order 2222 Presents Opportunity

A new potential market opportunity is on the horizon. Participation of DER in the wholesale energy market has typically been restricted to traditional demand-response schemes, but new market rules passed by the Federal Energy Regulatory Commission (FERC) are expanding DER access to bulk energy markets. Order 2222, passed by the FERC in 2020, allows DER aggregations to compete in the energy, capacity, and ancillary services markets operated by regional transmission organizations (RTOs) and independent system operators (ISOs); in other words, grid operators within FERC jurisdiction are now required to include aggregated DERs in their market structures (St. John 2020). The Order allows small utilities — those whose annual electricity sales are below 4,000,000 MWh — to decide whether to opt into the DER wholesale structures that ISOs and RTOs will establish to comply with the new ruling. The Order also requires RTOs and ISOs to establish a comprehensive procedure to ensure that distribution utilities can review the individual DERs that are part of an aggregation. Although the ruling is now effective, it will take time for the DER wholesale market to become active, especially as the country works to integrate utility grid operations with bulk energy markets.

- Additional Information on FERC 2222 https://www.cooperative.com/topics/power-supply-wholesale-markets/Pages/FERC-Order-2222-for-DER-Aggregation.aspx
- Contact for questions on FERC 2222: Paul McCurley, NRECA Chief Engineer: Paul.McCurley@nreca.coop

Other market opportunities are discussed in more detail later in the report in the context of specific value streams.

Incentives and Mandates

The availability of federal, state, or local incentives or mandates, such as renewable portfolio standards, will also affect the value proposition of distributed wind in a certain location and application. Incentives can come in the form of grants, direct payments, or tax credits.[4] Mandates can influence value, in that a distributed wind project may enable a cooperative to comply with a mandate, avoid a compliance penalty, and or avoid costs related to alternative methods of compliance.

Ownership Models

Distributed wind projects can be owned by utilities, community members, the energy end user, or third parties. For example, the energy from a front-of-meter wind project owned by a third-party or a community group can be purchased by a cooperative through a power purchase agreement (PPA). Similarly, the energy from a behind-the-meter project owned by a third-party can be purchased by the end user through a PPA. Community wind project owners can be individuals who form independent power producer groups or LLCs to sell the energy (Orrell 2021).

Business arrangements, such as project ownership arrangements, partnership structures, and contract structures, dictate who is responsible for operations and maintenance costs and major overhauls, how incentives or other compensation is allocated and monetized, and in general, which stakeholders accrue which benefits (Mongird and Barrows 2021). Consequently, business arrangements influence valuation.

Tariffs

Tariffs can both influence DER value and be influenced by valuation. For example, the development of a new tariff, and the electric rates within the tariff, to compensate DER-owners will be shaped by the utility's or state's valuation of such projects, in addition to any existing applicable regulations and incentives. In turn, the location, type, and size of a DER project that an owner installs will be influenced by the tariff compensation the owner expects to receive.

For example, net metering is a type of tariff under which distributed wind owners are compensated for their exported energy at the full retail electric rate. If there are demand charges in a tariff, they can be avoided if the time of energy generation from a net metered distributed wind project corresponds with peak load periods. As distributed wind projects are considered, utilities or other project owners can consider the applicable tariffs to understand the revenues and avoided costs that will result from the project.

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[4] Electric cooperatives are tax exempt entities and as such are not eligible to take advantage of most tax credits directly, but tax credits can still affect project economics through partnering with for-profit developers.

Value Streams Associated with Distributed Wind

Electric cooperatives and other stakeholders install wind projects for different reasons based on what is important to them. This section describes the different value streams, ones that are both quantifiable and ones that may be more difficult to quantify, or may be more qualitative in nature, that could be used as the basis of a decision to install a distributed wind project.

Most Common Distributed Wind Value Streams

The most common value streams associated with distributed wind include:

- **Gaining Experience with Distributed and Renewable Resources**

  Distributed wind can support utilities interested in gaining experience with DER. In NRECA Research's 2021 NRECA RADWIND Survey of distribution utility members, 40 percent of respondents indicated that increased experience with distributed generation is a benefit of distributed wind to the cooperative (NRECA 2021).

> *"G&Ts may gain experience and lessons learned to help their members build their own systems in the future. In addition, smaller distributed systems sometimes provide a less risky glide path to knowledge for G&Ts before jumping into a large, utility-scale project."*
>
> *(Moorefield and Roepke 2021)*

- **Meeting Member Demand for Green and Sustainable Energy**

  In the RADWIND survey, 34 percent of respondents indicated that meeting member demand for green and sustainable electricity was a benefit of distributed wind to cooperatives. Locally deployed distributed wind projects can provide a component of meeting this demand that is more visible to consumer-members than a large-scale transmission tied project that may be far away from the service territory.

- **Local Economic Development**

  Because distributed wind is local, building, operating, and maintaining distributed wind can support local economic development. In the RADWIND survey, 21 percent of respondents pointed to increased economic development as a benefit of distributed wind to the cooperative (NRECA 2021).

- **Price Predictability and Fuel Price Hedging**

  When purchasing wind energy through a PPA, the predictability of the purchase price may be highly valuable to the buyer when compared to the alternative of purchasing electricity at variable, or rising, wholesale or retail rates. Because distributed wind has no fuel cost, its energy generation can also serve as a hedge against future fuel supply cost increases.

- **Demand and Energy Cost Reduction**

  Distributed wind on a distribution cooperative system can reduce the demand for energy that must be obtained from a distribution cooperative's generation and transmission (G&T) cooperative or other wholesale supplier. If the LCOE of the distributed wind project is less than the LCOE of electricity from alternatives or the wholesale cost of electricity, the wind project can reduce the total cost of energy to the cooperative. Likewise, for individual cooperative consumer-members who install on-site distributed wind, it can reduce their demand and energy costs. Distributed wind projects can also reduce transmission costs, because they are on the distribution-side of a substation.

- **Reduced Need for New Transmission or Distribution Assets**

  Distributed wind can provide value to electric cooperatives in that it may delay or eliminate needed investment in additional transmission or distribution system infrastructure, especially when part of a hybrid power plant that includes other DER such as storage.

- **Reduce Peak Demand**

  Depending on the timing of distributed wind's generation profile relative to the system peak demand, a distributed wind project can reduce peak demand and associated demand charges. As part of reducing peak demand, distributed wind can also help defer the need for additional generation, transmission, and or distribution system upgrades.

- **Made in the USA**

  Wind turbine manufacturers and their supply chain vendors are located across the United States, in at least 27 states for small wind and at least 42 states for large-scale turbines. Small wind turbine manufacturers have self-reported that domestic content levels for their turbines range from 80% to 100%. The approximated domestic content for large-scale wind turbines ranges from 40% to 90% for blades and hubs, towers, and nacelles (Orrell et al. 2018; Wiser and Bolinger 2020).

The following sections describe other types of value streams relevant to distributed wind.

Levelized Cost of Energy of Distributed Wind Compared to Alternatives

The primary reason a utility or other entity would install distributed wind is to save money. This value stream can be quantified using LCOE. If the LCOE for a wind project is lower than alternatives, that provides an economic benefit to the utility or customer installing the distributed wind. Therefore, the primary potential value stream that distributed wind can provide is saving money due to a lower LCOE. When the LCOE of a distributed wind project is lower than purchased power prices (either wholesale or retail, as applicable) or the cost of new alternative projects, then the value contribution of the distributed wind project is its ability to reduce costs to the utility or project owner.

> The primary potential value stream that distributed wind can provide is saving money due to a lower LCOE.

LCOE refers to the overall capital and operating costs of energy from a power generation resource over a defined cost recovery period and is usually expressed in cents/kWh of energy generated. LCOE is often cited as a convenient summary metric of the overall competitiveness of different power generation technologies. Key inputs to the LCOE include initial capital costs, fixed operations and maintenance (O&M) costs, variable costs that include O&M and fuel costs, and energy generation. LCOE calculations can also include financing costs, future replacement costs, and degradation costs (NREL 2021).

Fuel costs are one input to the LCOE calculation. Because distributed wind has no fuel cost, as mentioned earlier, that benefit may lower its LCOE, but its energy generation can also, therefore, serve as a hedge against future fuel supply cost increases. The price predictability afforded by long-term PPAs can also help hedge against increasing power prices generally.

Additional Direct Revenue Streams

In some cases, additional direct revenue streams, for either the cooperative or the consumer-member owner, may be available and improve the distributed wind project’s cash flow. These include renewable energy certificates (RECs), carbon credits, and tax credits. These types of revenue streams may be realized only in certain states that provide the specific incentives or programs.

RECs are market-based instruments that represent the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. One REC represents one MWh of electricity generated and delivered to the grid from a renewable source (EPA 2019). RECs from distributed wind projects can be sold and, therefore, represent an additional potential revenue stream from a wind project. RECs from a wind project can also be kept and retired to demonstrate compliance with state renewable portfolio standard mandates.

Carbon credits, or carbon offsets, can also be associated with distributed wind projects that are able to demonstrate reduction in greenhouse gas emissions. For a project to be eligible to generate carbon credits or offsets, the project must be deemed to be additional (i.e., the project would not have happened without the carbon credit) and the resulting emissions reductions must be real, permanent, and verified; and the credits issued for verified emissions reductions must be enforceable (EPA 2018).

Tax credits can also significantly affect project economics. The federal investment tax credit, federal production tax credit, or other state tax credits can provide an additional revenue source that effectively reduces the cost of building or operating the wind project. As tax-exempt entities, electric cooperatives and rural public power districts are not eligible to take advantage of federal tax credits directly. However, there are partnering methods cooperatives can pursue with taxable entities, such as a tax-equity partnership flip (NRECA 2018) to monetize federal tax incentives. In addition, for-profit developers with tax appetites can use federal tax credits to provide a lower PPA rate to a cooperative, which would need to be addressed in the PPA negotiations.

Potential Generation, Transmission, and Distribution Benefits

If wind energy generation is coincident with peak demand, the distributed wind project has the potential to reduce the peak demand, system congestion, and capacity costs. The generation from a behind-the-meter project for a commercial or industrial customer could be coincident with the facility's load and thereby reduce the customer demand charges. For a front-of-meter project, if generation is coincident with peak demand, the project could reduce peak demand on a distribution system, which would reduce congestion and save on capacity costs. One of the key benefits of distributed wind is that it is local and can be sited closer to customers, thereby helping to avoid or mitigate distribution and transmission congestion and associated costs. Distributed wind in a hybrid power plant has the potential to further reduce peak demand and associated demand charges. For example, pairing wind with solar could reduce both winter and summer peak demand, or with battery storage, to generally reduce variability and allow the deferment of generation to peak times.

Through producing power at the times of peak demand, distributed wind, or distributed wind hybrid power plants, can potentially defer the need for additional generation, transmission, and or distribution system upgrades (Frick et al. 2021). Distributed generation, such as wind, can support a grid by improving power quality and reducing transmission and distribution costs and associated system losses (e.g., line losses), all of which ultimately enhance system power supply reliability (Wang et al. 2012).

Cooperatives considering generation, transmission, or distribution system upgrades can evaluate whether distributed wind, or distributed wind hybrids, could defer, reduce, or avoid the need for these upgrades. Generation capacity additions may also be avoided if the timing of distributed wind generation coincides with system peak load, or if a wind-storage hybrid is used. In general, hybrids including battery storage might be particularly useful in ensuring that output is predictable enough at the right peak times to defer or offset the need for system upgrades.

Other Benefits to Electric Cooperatives

In addition to the value streams listed in the Most Common Distributed Wind Value Streams section, respondents to the 2021 NRECA RADWIND Survey identified higher levels of member satisfaction, meeting sustainable energy mandates, increased generation capacity, more local generation, improved economic resilience within the community, and rate stabilization as benefits from distributed wind to electric cooperatives (NRECA 2021). Distributed wind generation provides the opportunity to meet not only local energy demand needs, but also state-level clean energy mandates.

Potential Grid Services Benefits

Wind is technically capable of providing a wide variety of services, such as frequency response, voltage support, and potentially even black start services (Denholm et. al 2019). Most grid services are enabled through smart inverters, and some require intelligent forecasting, advanced controls and pre-curtailment of the wind project, to be able to ramp up to provide flexibility to support the grid. Ongoing research and development of inverters for distributed wind turbines is increasing the ability of distributed wind projects to provide grid services.

- **Regulation**

  Regulation service is used to balance small fluctuations between supply and demand automatically and continually in real time. Market operators can request regulation up or regulation down to keep the grid balanced. Generation units that provide regulation must respond to a signal within a given time frame, usually five minutes (Zhou et al. 2016).

  Regulation up means that a wind turbine would increase power output in response to a signal.

  Regulation down means that a wind turbine would reduce power output in response to a signal.

  Wind turbines can respond to a regulation down signal readily through inverters that can reduce the power output from the wind turbine. For a wind turbine to provide regulation up, the turbine would need to be operated in a pre-curtailed mode, where headroom is kept available to increase wind production. Because providing regulation up requires operating the turbine in a pre-curtailed mode, the wind system operator needs to consider the economic trade-offs between operating in a pre-curtailed mode to provide regulation up services, versus maxing out generation. Being able to provide this regulation up service would require more advanced control schemes. Where a regulation market is available, wind turbines can be part of those market transactions. Regulation up and regulation down are separate market products in CAISO, ERCOT, and SPP. In ISO-NE, MISO, and NYISO, a generic five-minute regulation product is offered (Zhou et al. 2016).

- **Primary Frequency Response (Inertia)**

  North American Electric Reliability Corporation (NERC) Standard BAL-003-1 requires that balancing authorities maintain sufficient frequency response capacity to maintain interconnection frequency within predefined bounds. In compliance with NERC Standard BAL-003-1, NERC establishes frequency response obligation allocations for each of the four interconnections in the United States, and those obligations are in turn transferred onto balancing authorities within each interconnection. Wind turbines can provide energy to maintain frequency stability when it deviates outside the set limits, thereby keeping generation and load balanced within the system. There are not explicit market products associated with frequency response, but a bilateral contract can be entered into between utilities and within balancing areas for frequency response. The technology exists and is mature for smart inverters to provide frequency response, but that technology is not commonly used with distributed wind.

- **Load Following**

  Load following is similar to regulation, in that it refers to adjusting power output in response to changes in load to balance supply and demand. Load following can be achieved with wind through smart inverters and advanced controls. No current markets exist for load following, but it can be valuable to a grid that wants to limit exports or otherwise balance load with supply.

- **Voltage Support**

  Voltage support refers to generation units injecting or absorbing reactive power to help maintain voltage levels of the grid within acceptable levels. Because distributed wind is located closer to loads, it can provide localized voltage support. This may be particularly useful in rural areas with long distribution feeders. Similar to other generation resources, wind power plants are also subject to voltage regulation requirements per their interconnection agreements. Additional voltage support for the grid as an ancillary service can be provided through wind turbine inverters. Most markets do not offer compensation for voltage support, but system operators must ensure voltage remains within acceptable bounds, and wind projects can be part of providing reactive power, through inverters, to support the grid.

- **Black Start**

  Many power generators require input energy to start up and begin operating. For isolated grids or microgrids, wind turbines in combination with other generating units can provide black start support. There are no markets for black start, but black start can be valued as a technical service with associated avoided costs and can be essential for isolated grids.

  Black start refers to the capability that a power grid must be able to maintain, to restore operations in the event of a mass outage (Zhou et al. 2016).

- **Flexible Ramping**

  Flexible ramping is similar to load following and regulation, in that it refers to the ability for generators to adjust up or down in response to system needs. Specific controls are needed for wind turbines to provide flexibility ramping, and the ability to provide ramping may be limited by wind resource availability, which can be indicated in forecasts. Pre-curtailment may also be required, which may limit energy generation by wind turbines. Flexible ramping is not an existing market product, but CAISO has been considering a flexible ramping product.

Potential Financial Costs to Electric Cooperatives

New distributed energy programs or initiatives can introduce new costs to a cooperative, most typically administrative, insurance, and interconnection costs. Potential lost revenue due to electricity self-supply from behind-the-meter projects can also be considered a financial cost to a cooperative. If a utility introduces a DER compensation or new interconnection program for customers interested in installing on-site behind-the-meter DER, for example, there are typically administrative costs to the utility associated with implementing and maintaining the program. There can also be capital costs associated with equipment and technologies needed to interconnect the DER. Administrative costs can include marketing, program application evaluation, interconnection review, insurance, and measurement and verification (Wolf et al. 2014).

Other Potential Costs

Beyond direct financial costs to electric cooperatives themselves, there may be potential costs as a result of wildlife impacts, environmental effects, and human-environment interactions. However, these types of costs vary greatly depending on the project scale. To illustrate, in the U.S. Fish and Wildlife Service’s 2012 “Land-Based Wind Energy Guidelines” handbook, the agency states that distributed wind projects are typically planned for limited geographic areas with low environmental risk concerns and that they do not anticipate such projects requiring additional evaluation beyond Tiers 1 and 2 of the Guidelines approach (i.e., preliminary site screening and site characterization). The handbook acknowledges that the environmental burdens posed by utility-scale wind farms are far more significant than those of distributed wind energy projects (USFWS 2012).

Wind energy projects can have ecological and environmental effects, the most notable including the loss or degradation of wildlife habitat and avian fatalities resulting from collision with land-based structures (NRC 2007). According to the National Wind Coordinating Committee (NWCC), fatalities of birds and bats are highly variable among facilities and regions of the country, but impacts to wildlife are comparatively low: bird and bat deaths due to turbine collisions, changes in air pressure caused by the spinning turbines, and habitat disruption generally do not pose a significant threat to species populations (NWCC 2010). Potential wildlife concerns are typically mitigated through the turbine siting process. The USFWS found that appropriately sited small wind projects are not likely to pose significant risks to species of concern (USFWS 2012). If necessary, some potential wildlife impacts can also be addressed through best management conservation practices, such as the curtailment of facility operations during migratory periods.

Other potential costs associated with the development and operation of wind energy facilities include public health concerns around turbine sound and shadow flicker. Modern turbines have many features capable of controlling sound emissions (e.g., insulation of the nacelle and gearbox) and do not produce sound at levels that can cause hearing impairment, but there have been reports of increased annoyance, stress, irritation, and sleep disturbance in individual cases, especially at sound pressure levels greater than 40 dB(A) (Knopper and Ollson 2011). However, there is evidence to suggest that wind turbine sound annoyance is mostly a function of individual perception and experience, rather than an objective response to wind turbine sound level – that is, an individual is more likely to experience annoyance if they object to the project itself (Haac et al.).

Another potential human-environment interaction is shadow flicker. There is no strong epidemiological evidence to link shadow flicker to serious health effects; studies assessing the impact of flickering on individuals with photosensitive epilepsy have revealed that turbines are unlikely to induce an epileptic response (Knopper and Ollson 2011). To date, no peer reviewed articles demonstrate a direct causal link between wind turbine sound or shadow flicker and physiological health effects (Knopper and Ollson 2011).

Shadow flicker occurs when rotating wind turbine blades cast shadows on the ground or on nearby structures, usually at sunrise and sunset.

Although there are no known health effects caused by exposure to shadow flicker or sound, siting software can be used by developers to model and calculate expected shadow flicker and sound levels for stakeholder engagement purposes or to know when turbines may need to be curtailed to mitigate concerns (EMD 2021; Priestly 2011).

Sound and shadow flicker concerns can also be mitigated by establishing proper setback distances between turbines and nearby residences. Related to setback distances is the concern in some communities that wind projects may negatively affect local property values. An analysis conducted by Lawrence Berkeley National Laboratory revealed that property value impacts on single-family homes located within 10 miles of wind facilities were too small or infrequent to result in any widespread, statistically observable impact, although it is still possible for home values to be negatively affected by proximity to a wind facility (Hoen et al. 2014).

Although costs from wildlife impacts, environmental effects, and human-environment interactions are relative to the scale of the project, all projects, regardless of scale, must comply with the permitting requirements of the authority having jurisdiction.

Consumer-Member and Society Benefits

DER can provide a number of economic, educational, technical, and health benefits to consumer-members and the local community. In terms of economic development, distributed wind energy projects may create jobs within and around the local community, provide a new source of revenue for landowners in the form of lease payments, and contribute to community tax revenue. DER can directly increase economic community resilience for the aforementioned reasons, but may also indirectly enhance the local economy through increased spending at hotels and restaurants during the construction phase of a project (especially if construction services and companies are sought from outside the community) (DOE 2021b).

Distributed wind projects can also be an educational asset to the community. First, such projects can provide a tangible local resource as an introduction to renewable energy, including the opportunity for touring and educational programs with younger (K-12) students. Second, distributed wind projects, especially locally-owned community wind projects, provide an opportunity for community stakeholders and affected landowners to be involved in the siting and economic decision-making processes. Third, by creating job employment opportunities, distributed wind projects may also expand technical and service training programs at the local level (e.g. in partnership with local community/technical colleges) and engender an opportunity for community members to become familiar with relevant renewable energy policies. Last, experience with distributed wind projects can prepare a community for future distributed generation development opportunities.

Distributed generation can also provide several benefits to consumer-members and the community including mitigating outages and improving community resilience. In the case of Arizona G&T Cooperative, the development of distributed generation capacity was critical to deferring upgrade costs for the transmission line to their distribution cooperative, Anza. This also prevented the danger of exceeding the capacity of the existing single radial transmission line, which had been subject to outages due to wildfires (Moorefield and Roepke 2021; Ahlen and Gibson 2021). Compared to centralized generation, distributed generation also offers the advantage of reduced interruptions due to transmission and distribution outages (Wang et al. 2012). Additionally, distributed generation can play a vital role in resilience planning for critical community infrastructure and at critical facilities, such as wastewater-treatment plants or communications facilities.

Other benefits to society can include avoided greenhouse gas emissions and the associated health benefits of reduced pollution. A distributed wind project does not require mining, drilling, or transportation of fuel and it does not have the risk of of large-scale environmental contamination. Distributed wind projects also require minimal amounts of water to operate (NREL 2012).

Consumer-Member Owner Benefits

Distributed wind projects can provide a wide range of benefits to the consumer-member owners of the projects, from economic savings (primarily through the reduction of utility bill charges) to achieving corporate sustainability goals for commercial and industrial members. By generating part, if not all, of their energy consumption needs, an owner can offset their utility's energy and demand charges, resulting in significant economic savings over the lifetime of a project. Corporate sustainability goals are also driving distributed generation development. Corporate entities can tout their use of green power through either projects that they own and operate themselves, or through PPAs with other entities. PPAs are increasingly common for corporate entities. Through PPAs corporate entities provide wind project owners with a financing mechanism for their projects, while corporations are able to "take credit" for helping to bring the renewable energy project online (Moorefield and Roepke 2021).

Another driver for consumer-owners is federal, state, and utility incentives. In particular, owners can benefit from federal tax incentives, or credits, for qualifying distributed generation projects. For example, the federal Business Energy Investment Tax Credit (26 U.S.C. § 48) and the Residential Renewable Energy Tax Credit (26 U.S.C. § 25D) are federal policy mechanisms that offset some of the capital costs of qualified renewable energy projects. Under the Consolidated Appropriations Act of 2021, small wind turbines' eligibility for the Business Energy Investment Tax Credit of 26% of qualified expenditures has been extended through 2022, with a scheduled phasedown to 22% for properties that begin construction by the end of 2023, after which the credit expires. The Residential Renewable Energy Tax Credit will remain at the current 26% rate through 2022 and reduce to 22% for property placed in service through 2023, after which the credit ends (Public Law 116-260 as of December 27, 2020). The federal production tax credit (PTC) for onshore wind, scheduled to expire on December 31, 2020, has also been extended through December 31, 2021 under the Consolidated Appropriations Act 2021. Projects that begin construction by the end of 2021 will be eligible for a PTC at 60% of the full rate over 10 years, or alternatively, can opt for an 18% investment tax credit (ITC) on the total project cost in the year the project is placed in service.

Tools

There is currently no comprehensive valuation tool for distributed wind that captures all value streams, quantitatively or qualitatively. Pacific Northwest National Laboratory (PNNL) has created a distributed wind valuation framework that will eventually be the basis of a user-friendly valuation tool (Mongird and Barrows 2021).

For now, a variety of tools are available that electric cooperatives and developers can use to estimate project economics using various metrics. These tools, along with a short description and how they can be used, are included in Table 1. These tools can be used as starting points in understanding a distributed wind project's potential value.

Table 1: A Selection of Modeling Tools for Distributed Wind

Tool	Developer	Technologies	Description	Accessibility
Cost of Renewable Energy Spreadsheet Tool (CREST)	National Renewable Energy Laboratory (NREL)	– Wind – Solar PV – Geothermal – Anaerobic Digestion – Fuel Cell	CREST is designed for state policymakers, regulators, utilities, developers, and investors. The cost-of-energy analysis tool can be used to determine the cost of energy, or minimum revenue per unit of production, needed for a renewable energy project to meet its investors' minimum required after-tax rate of return.	Free. Easy to use cash flow model spreadsheet with a user manual.
System Advisor Model (SAM)	NREL	– Wind – Solar PV – Battery Storage – Marine Energy – Concentrating Solar – Solar Water Heating – Biomass – Geothermal	SAM can model the performance of a variety of technologies along with different business and financial models (i.e., PPA, residential owner, merchant plant).	Free. Wind resource data and turbine options are built in or can be added manually.
Distributed Energy Resource Value Estimation Tool (DER-VET)	Electric Power Research Institute (EPRI)	– Wind – Solar PV – Demand Response – Electric Vehicle Charging – Internal Combustion Engines – Combined Heat and Power	An open-source platform for calculating, understanding, and optimizing the value of DER in utility grids and microgrids based on their technical merits and constraints, including grid services and locational value.	Free. Uses Python and could be connected to grid simulation tools, such as OpenDSS.
Locational Net Benefit Analysis (LNBA) Tool	Energy + Environmental Economics (E3)	– Wind – Solar PV – Other	Specifically designed to identify DER locational benefits by comparing the DER value to a specific utility investment. Applies to single a DER or a suite of DER.	Free Spreadsheet tool with user guide that requires utility-specific inputs.

Table 1 (Continued)

Tool	Developer	Technologies	Description	Accessibility
Jobs and Economic Development Impacts (JEDI) Wind model	NREL	– Wind	JEDI allows the user to estimate economic development impacts from wind power generation projects. The model has default information that can be used to run a generic impacts analysis assuming wind industry averages, or users can enter project-specific data for more targeted results.	Free. Spreadsheet model that requires user inputs including project capital, construction and O&M costs; turbine and land lease information; and tax and financing information.
Hybrid Optimization of Multiple Energy Resource (HOMER)	UL	– Wind – Solar PV – Generators – Hydro – Combined Heat and Power – Hydrogen – Custom Component	HOMER products are designed to model distributed generation in microgrids, isolated grids, and behind-the-meter projects using one or more technologies.	Cost. Downloaded, desktop software. Company can provide training and support.

Summary

Distributed wind, and distributed wind hybrids, can contribute a range of values, beyond the traditional metric of a cost-competitive LCOE. In order to make informed decisions about distributed wind deployment, stakeholders must identify, characterize, and then (to the extent possible) quantify the value streams relevant to them. Stakeholders will have different perspectives (i.e., a cooperative evaluating a large front-of-meter distributed wind project compared to a consumer-member considering a 10-kW behind-the-meter wind turbine), which in turn will drive their different approaches to valuation.

As electricity markets evolve, electric cooperatives can be forward thinking in considering what values distributed wind (alone or in hybrid power plants) could provide to them both now and in the future – beyond the more traditional benefits, such as cost savings. This report provides specific characteristics of distributed wind, factors that can influence value, and value streams relevant to distributed wind to consider when evaluating what value distributed wind could bring to a cooperative’s community.

Next Steps

The Business Case report is the next report in this series. The Business Case report will investigate and present various business and financial structures that could be used to realize the various quantifiable value streams, and could assist in creating a framework that rural electric cooperatives can use to explain a distributed wind solution to its board or members.

Additional Information on NRECA Research's RADWIND Project

For more information on the RADWIND project and additional resources, please visit the project landing page at www.cooperative.com/radwind.

Want to stay informed of our progress with the RADWIND project and provide your input and feedback? We welcome all NRECA voting members to join the project as an advisor. Contact our team at: RadwindProject@nreca.coop.

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