Business & Technology Strategies

TechSurveillance

Current Wind Generation Technologies

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SUBJECT MATTER EXPERTS FOR QUESTIONS ON THIS TOPIC

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This is the second in a series of NRECA TechSurveillance *articles about the status of the wind generation market and its impact on cooperatives. The first article provided an overview of how much wind generation capacity electric cooperatives currently own and purchase, and how they do it. This article focuses on current and advanced wind technologies, and the third article will examine failure and maintenance issues. Visit* **cooperative.com** *for the entire series, as well as other helpful resources from NRECA.*

ARTICLE SNAPSHOT:

What has changed in the industry?
Wind energy is now considered a mature technology, and new turbines with advanced controls enable the use of lighter materials, taller towers, and increased energy production. See **Figure 1** for an example of a utility-scale wind farm.

Wind farms' impacts on wildlife, particularly birds and bats, are better understood than they were a decade ago (and surprisingly the impacts are not as significant as was once thought), and new research is actively underway to continue to mitigate effects on specific populations of birds and bats.

Wind farm financing is also changing because the Production Tax Credit (PTC) is phasing-out. In 2016, the PTC was $23/MWh and in 2017 is now 20 percent lower at $18.4/MWh, and will continue to decrease by 20 percent per year until phased out. New projects can still qualify until January 1, 2020, and once started, the PTC lasts for ten years. By repowering older wind turbines with longer blades and overhauled drive trains, the PTC can be extended for another ten years, annual energy production increases by 20 percent, and the project will last for an additional 20 years.

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What is the impact on cooperatives?

Given PTC phase-out, it may make financial sense for co-ops that are not located in energy markets (like SPP, MISO, ERCOT, etc.) to own or self-finance wind farms using their 100 percent low cost debt financing, rather than purchasing through PPAs with wind developers using a combination of high cost equity and higher cost debt. However, those co-ops located in energy markets will need to continue to purchase wind energy from PPAs or form joint ventures/Limited Liability Partnerships with taxable entities to utilize the PTC to be able to compete in markets where the PTC causes low or even negative energy prices. Wind farms with the latest technology may likely become cost-effective renewable options for electric cooperatives that are not in energy markets. But, electric cooperatives will have to either develop the skills to operate and maintain the wind farms or enter into long-term service agreements with developers or manufacturers.

FIGURE 1: Utility-Scale Wind Farm
(Source: NREL)

What do co-ops need to know or do about it?

Electric cooperatives should stay up-to-date on technology improvements, evaluate current pricing and financing options, consider wind's role in future generation mixes, and evaluate the implications of intermittent and non-dispatchable wind generation.

INTRODUCTION

Wind turbines are advanced, modern versions of windmills which have been used for thousands of years to pump water and grind grain into flour. In 2016, wind outpaced hydro-electric by providing 8 percent of U.S. generating capacity, and generated more than 5.5 percent of our nation's electricity.[1,2] As the wind industry grows, manufacturers are improving equipment, control, and service options to continue to bring down the cost of wind energy, especially as the PTC phases out over time. Wind energy provides the highest-capacity and lowest-cost renewable and sustainable source of energy in those regions that have excellent wind resources.

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WIND TURBINE COMPONENTS

Utility-scale wind turbines have three main sections — rotor, nacelle, and tower — each with multiple components, as shown in Figure 2.

Rotor

The **rotor** is composed of **blades** attached together on a **hub**. Today's wind turbines typically have three blades that rotate on a horizontal axis; however, some models have two blades and/or rotate on a vertical axis. The **pitch system**, located in the hub, can turn (or feather) blades individually to control speed and reduce vibration by changing the angle that the wind contacts each blade. Rotor size can be described by blade length (feet or meters),

[1] https://www.eia.gov/electricity/monthly

[2] https://www.eia.gov/todayinenergy/detail.php?id=31032

PREVIOUS VIEW

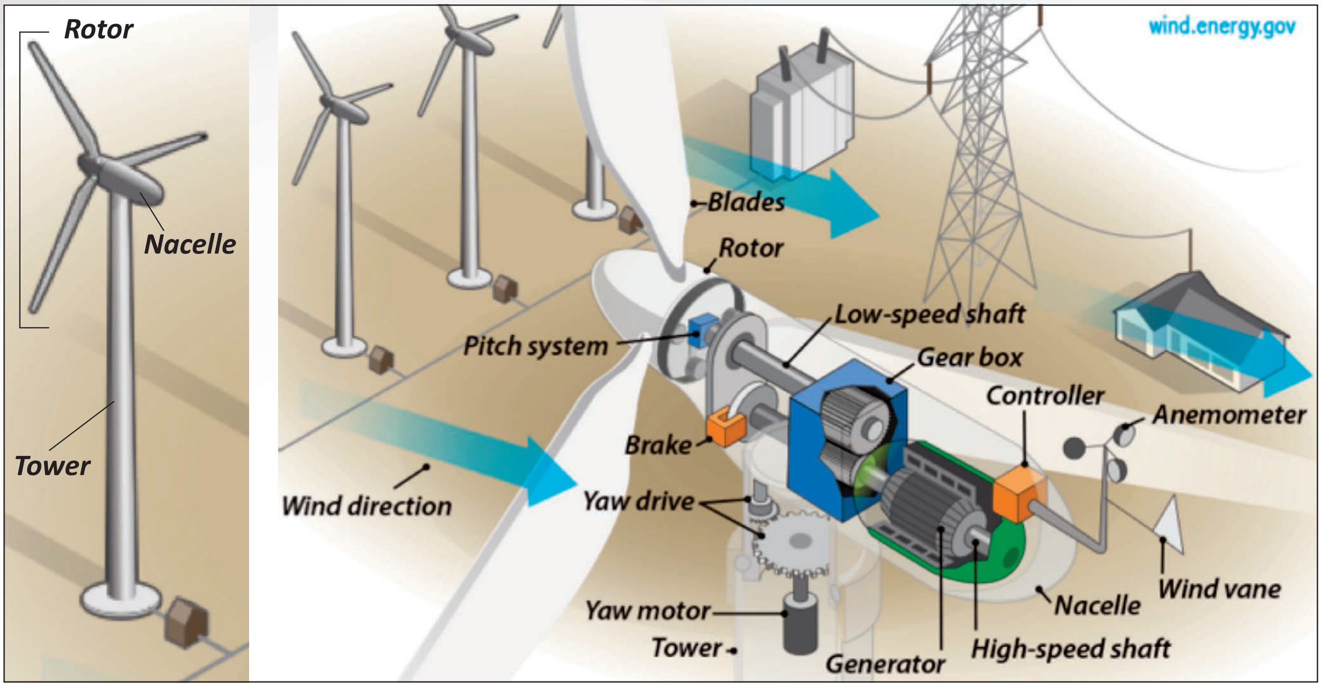


FIGURE 2: Wind Turbine Components *Source: EERE*

diameter of swept area (feet or meters), or swept area (square feet or square meters).

Nacelle

The **nacelle** houses the power generation equipment, including the **gearbox**, **generator**, and **controller**. When the wind blows, the rotor spins a **low-speed shaft** that rotates at approximately 30 to 60 rotations per minute (rpm). The low-speed shaft contacts a **high-speed shaft** inside the **gear box**. The high-speed shaft typically spins somewhere between 1,000 and 1,800 rpm. The high-speed shaft connects to a **generator**, which produces 60 Hz frequency (using a frequency converter system that today is characterized by a compact, modular design with a high power density), alternating current (AC) electricity that is then fed into a substation and ultimately the grid. Some newer wind turbines have direct drive systems that eliminate the need for a gearbox, which is a major source of maintenance and outages. The nacelle also contains a **controller** to tell the turbine when to operate or not depending on wind speed, temperature, and requirements of the grid (possible congestion, system voltage, etc.); as well as mechanical, electrical, and/or hydraulic **brakes** to stop the rotors from spinning in an emergency.

Tower

The nacelle sits on top of the **tower**, which is typically hollow steel but can also be prestressed concrete or steel lattice. They support about 100 tons — the combined weight of the rotor and nacelle — plus the tower itself. Towers can be 15 to 20 feet in diameter, and contain ladders and lifts to access rotors and nacelles, and electrical cables. Because wind speeds are commonly higher at higher elevations, taller towers enable increased annual energy production (AEP). **Yaw drives** with large gears found at the top of towers turn the entire rotor/nacelle units, so that they face directly into the wind.

For more information, visit the following U.S. DOE websites: https://energy.gov/eere/wind/inside-wind-turbine-0 and https://www.energy.gov/articles/top-10-things-you-didnt-know-about-wind-power

Because wind speeds are commonly higher at higher elevations, taller towers enable increased annual energy production (AEP).

INNOVATIVE TOWER DESIGN

With funding from the DOE's Small Business Innovation Research (SBIR), Wind Tower Systems LLC (WTS), now Wasatch Wind LLC, of Heber City, Utah, developed a modular steel Space Frame tower design that is the most weight- and cost-effective tower design on the market, scaling to 100 meters in a linear cost relationship. This tower can reduce the cost of wind energy by up to 12 percent. The installed cost of the 100-meter Space Frame tower with an integrated lifting system is the same as a typical 80-meter tubular tower and a crawler crane installation. And, the additional 20 meters of height enables increased energy production from higher wind speeds. The Space Frame tower can be used by turbines up to 3 MW. In 2011 (DOE 2010), GE acquired this technology from WTS,* and now offers it as part of their product line.**

The innovative design — a steel Space Frame tower wrapped in non-structural architectural fabric (to reduce risks to birds) — "opens new heights and locations to wind energy by significantly reducing the costs associated with manufacturing, transporting, and installing the towers, both on land and offshore" (DOE, 2010, p. 2). Major advances achieved by the Space Tower are:

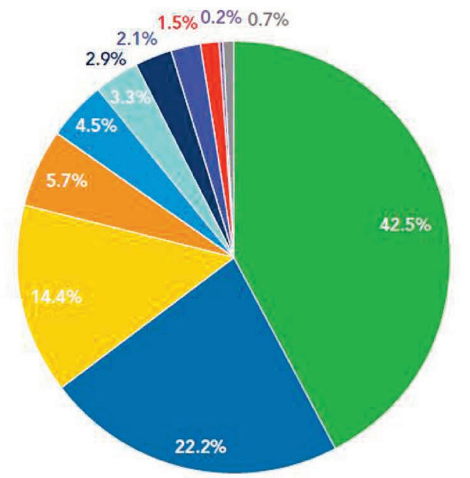
- reducing tower weight by 30 to 50 percent, compared to conventional tubular-steel towers
- reducing wind project developers' cost of building wind farms by 3 to 5 percent for the same size installation
- reducing transportation and construction risks via non-specialized transportation (standard flatbed trucks instead of expensive transportation permits and shipping carriers)
- eliminating crawler cranes due to integrated tower-climbing "gin-pole" device
- taking advantage of the stronger winds available at 100 meters height
- enabling economical development of small and hard-to-access wind sites (DOE, 2010, p. 2)

* http://www.wasatchwind.com/about-wasatch-wind/news-and-media/ge_wts

** https://www.gerenewableenergy.com/wind-energy/technology/space-frame-tower

WIND TURBINE TECHNOLOGY AND PERFORMANCE

In the U.S., three wind turbine manufacturers dominate the market — General Electric (GE), Vestas, and Siemens Gamesa (see Figure 3). (Note that Siemens Wind Power and Gamesa merged in April 2017, after this graph was published.) All three offer onshore and offshore wind turbines, control software, and service packages.



Ranking	Company	Capacity (MW)
1	GE Renewable Energy, Alstom, Enron, Zond, Tacke	34,883
2	Vestas, NEG Micon, Micon, Nordtank, NedWind, Wind World	18,281
3	Siemens, Bonus	11,833
4	Gamesa	4,661
5	Mitsubishi	3,738
6	Suzlon	2,685
7	Acciona Windpower, Nordex	2,356
8	Clipper	1,698
9	Senvion	1,255
10	Goldwind	176
	Others	577

FIGURE 3: Wind Turbine Manufacturers' Market Share of Us Wind Power Fleet *(Source: AWEA)*

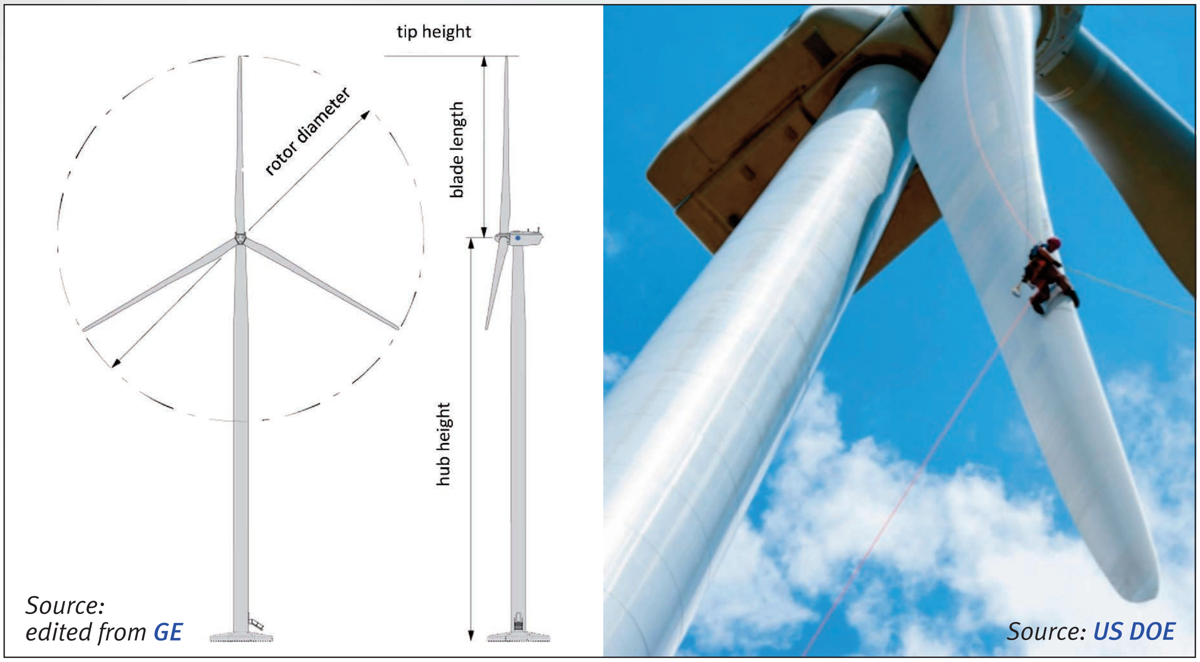


FIGURE 4: Wind Turbine Dimensions and Scale

Today's onshore wind turbines are the size equivalent to rotating a football field in the sky.

Physical Size

When viewing wind turbines in a distant field, it is hard to appreciate their scale. Today's wind turbines designed for land applications (onshore) have hub heights that average 80 meters, with 100 meter average rotor diameters (see Figure 4). This is equivalent to rotating a football field (91 meters long) in the sky. The Statue of Liberty, at 93 meters tall, would look small in a modern wind farm. Compare this to the early 2000s, when the average hub height was around 60 meters, and rotor diameters were between 50 and 60 meters (Bollinger & Wiser, 2016).

Specifications & Performance

Utility-scale wind turbines, particularly those sold by the top three manufacturers, have held up very well over time. While there have been some unexpected gearbox failures — a topic NRECA will cover in a subsequent report in this series — in general, wind turbines are lasting for their expected lifetimes with very high availability. Performance varies according to farm location (especially depending upon the degree of local turbulence) and make and model of wind turbines. Summary data from U.S. onshore wind projects follows:

- **Nameplate capacity:** Average nameplate capacity is increasing. In 2015, it was 2 MW, up from 1.8 MW in 2010, and <0.9 MW in 2000 (Bollinger & Wiser, 2016). Today, 2.6 MW and 3 MW plus wind turbines are being offered.
- **Capacity factor:** The average 2015 capacity factor among projects built in 2014 was 41.2 percent, compared to an average of 31.2 percent among all projects built from 2004–2011, and 25.8 percent among all projects built from 1998–2003. Wind farms in the U.S. interior had the highest average capacity factor at 42.7 percent (Bollinger & Wiser, 2016). Capacity factor varies according to local wind resource, annual weather patterns, turbine height, and rotor diameter.
- **Capacity value:** A key issue with wind is that, in the past, usually only 10 to 15 percent of the wind generator nameplate capacity was coincident with winter peak load

Since wind is intermittent and non-dispatchable, power systems will need to have backup reserves of fast ramping technologies or energy storage.

Sensor data combined with SCADA allows operators to manage the farm on-site or from off-site regional or global centers that control many wind farms.

demands; therefore, wind was primarily a source of energy. However, a study evaluating wind resources in western Kansas and Oklahoma determined a capacity value of nearly 40 percent coincidence with summer and winter peaks, though fluctuations in wind are largely uncorrelated with fluctuations in system load (AWS True Power, 2010). Since wind is intermittent and non-dispatchable, power systems will need to have backup reserves of fast ramping technologies or energy storage. For more information on ramping technologies, see NRECA's series on ***Addressing the Variability and Uncertainty in Renewables' Generation to Support Integration to the Grid***

- **Availability factor:** Wind turbines have very high availability factors — 98 percent or greater (DOE, 2015).
- **Grid support features:** Modern wind turbines have low-voltage ride-through (turbines stay on-line through grid voltage drops) and frequency response capabilities (turbines increase or decrease production to maintain nominal grid frequency) (DOE, 2015).
- **Lifetime:** Wind turbines are certified for 20-years by most manufacturers (DOE, 2015), and after 20 years the wind turbines can be repowered for less cost than a new wind turbine, and will last another 20 years.
- **Warranty:** Two years is typical, but service agreements can be purchased for longer terms, such as ten years, but terms may be negotiated. Some now cover the entire design life (DOE, 2015; GE[3]).

Controls

Modern wind turbines utilize dozens of digital controls and sensors to maximize energy production, reduce costs, and monitor maintenance needs of components. Traditionally, turbines can be controlled to optimize individual turbine performance, but this is increasingly shifting to optimizing cumulative output of the entire farm. Sensor data combined with SCADA allows operators to manage the farm on-site or from off-site regional or global centers that control many wind farms. Sensors and advanced control schemes can be added to older model wind turbines when they are repowered (DOE, 2015).

Wind direction sensors are used to monitor wind speed and wind direction; yaw motors between the tower and the nacelle are constantly working to turn the nacelle, ensuring the rotor is pointed into the wind. Sensors on blades and pistons at the root of the blades allow ongoing adjustments to individual blade pitch (or angle) against the wind, to maximize power output in normal winds, curtail rotor speed in very high winds, and reduce structural stress and vibration of components to within design tolerances. According to Joel Mathewson of Siemens Gamesa, blade pitch may continually change during the course of a single rotation to account for different wind speeds at different heights.[4] In addition to maximizing efficiency, fine-tuning of turbine performance enables the use of lighter-weight materials and longer blades, since it reduces vibration and physical stress. Other condition monitoring sensors detect when and what kind of maintenance is required.

Identifying issues before a component is broken can avoid the need for a costly repair and crane rental. For example, GE offers PulsePOINT, a proprietary advanced monitoring and diagnostics system that combines data from sensors on all moving parts of the turbine with customer SCADA information to identify mainte-

[3] Information presented by GE staff, May 2017, to NRECA in Greenville, SC

[4] Personal communication, July 20, 2017

nance needs before they become unplanned repairs. The manufacturer claims that PulsePOINT decreases turbine downtime by an average of 18 percent (about 32 hours) per year and lowers O&M costs. All turbines covered under GE full-service agreements have PulsePOINT installed.[5]

COSTS

Installed Costs

The capacity-weighted average installed cost for U.S. onshore wind farms constructed in 2015 was approximately $1,690/kW, which is $640/kW less than installed costs for 2009 and 2010. Installed costs varied with project size and location; a significant price drop occurred for projects that were 5 MW or larger (Bolinger & Wiser, 2016). The 2017 Annual Energy Outlook showed total overnight capital cost in 2016 as $1,686/kW.[6] Lazard (2016) shows a range of capital cost for wind depending upon ambient wind speed and location of $1,200/kW up to $1,700/kW.

Cost of Energy

As technologies improve, rotor diameters get larger, and the towers get taller, the levelized cost of energy (LCOE) from wind farms drops (see Figure 5). Lazard's 2016 *Unsubsidized Levelized Cost of Energy Analysis* shows onshore wind ranging from $32 to $62/MWh. At the low end of the range, wind has the lowest LCOE of all sources of alternate and conventional energy (Lazard, 2016). Assuming a capital cost of $1,686/kW, a 20-year life, 100 percent debt financing by an electric cooperative, and $37/kW year for fixed operating costs (approximately $9/MWh); the levelized cost of electricity will be about $42/MWh without the production tax credit.

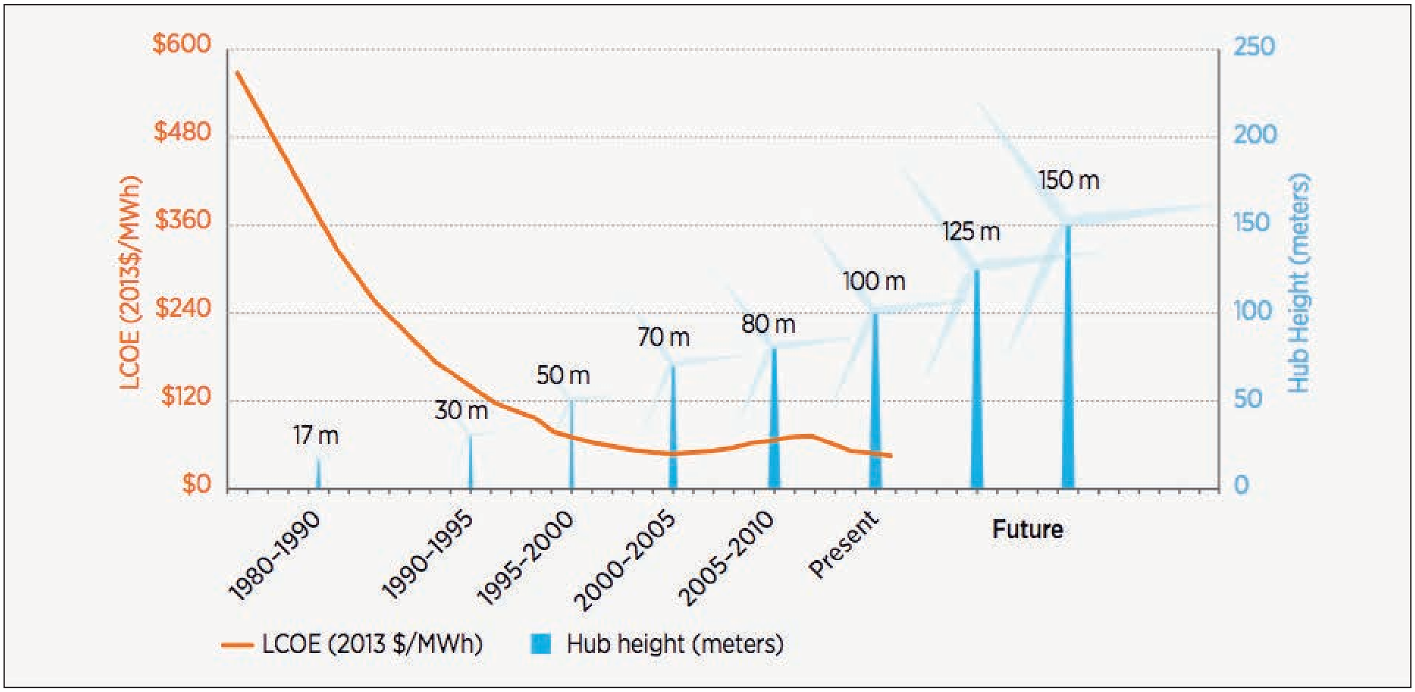


FIGURE 5: Wind Technology Scale-Up Trends and the Levelized Cost of Electricity *(Source: DOE, 2015, p.63)*

[5] GE PulsePOINT presentation, copyright 2014

[6] https://www.eia.gov/outlooks/aeo/assumptions/pdf/table_8.2.pdf

However, in the context of wholesale markets, wind generators, like other renewable resources, are considered to have a “zero marginal cost” for energy. This comes from the fact that wind and other renewables have no fuel costs, which is the primary driver of marginal cost in the wholesale energy market. These resources are also non-dispatchable and typically offer their energy into the market with a zero bid in order to clear the market. Therefore, they are usually price takers and are paid whatever clearing price is set for energy by the other generating units clearing the market in each dispatch interval. High levels of wind generation in a market would tend to lower overall clearing prices in the market due to their zero marginal cost characteristics and zero offer price into the market. Cooperatives operating in wholesale energy markets should be aware of the price impact potential for high levels of renewable generation. They should also be aware of the potential market distortions that arise from the impacts the PTC on market operations. The PTC subsidy allows wind generators to operate in low or even negative locational marginal pricing (LMP) intervals during low load periods, typically overnight and shoulder seasons (spring and fall). This tends to push market LMPs even lower, which puts pressure on other generators, like fossil units, to come off-line or face potential negative prices to run (i.e., they would have to pay to stay on-line if scheduled by the market). If these low or negative prices cause units to shut down that may be needed for reliability during increasing load periods, then market operators typically have to commit additional resources out of market, which also tends to decrease LMPs and make the market less efficient. In addition, any wind farm’s capacity factor (and demand factor) without a PTC will likely be reduced due to the low or negative LMP pricing periods, or have to face the same market penalties as fossil generators during the periods (possibly reducing a capacity factor from 50 percent down to capacity factors in the 30s or 40s due to low market LMPs).

Since wind resources are non-dispatchable, they are paid whatever clearing price is set for energy by the other generating units clearing the market in each dispatch interval.

Figure 6 shows the percent of time when renewable wind and solar generation had to be curtailed due to transmission congestion caused by excess wind and solar generation. The renewable generation curtailment is an indicator of low or negative market prices.

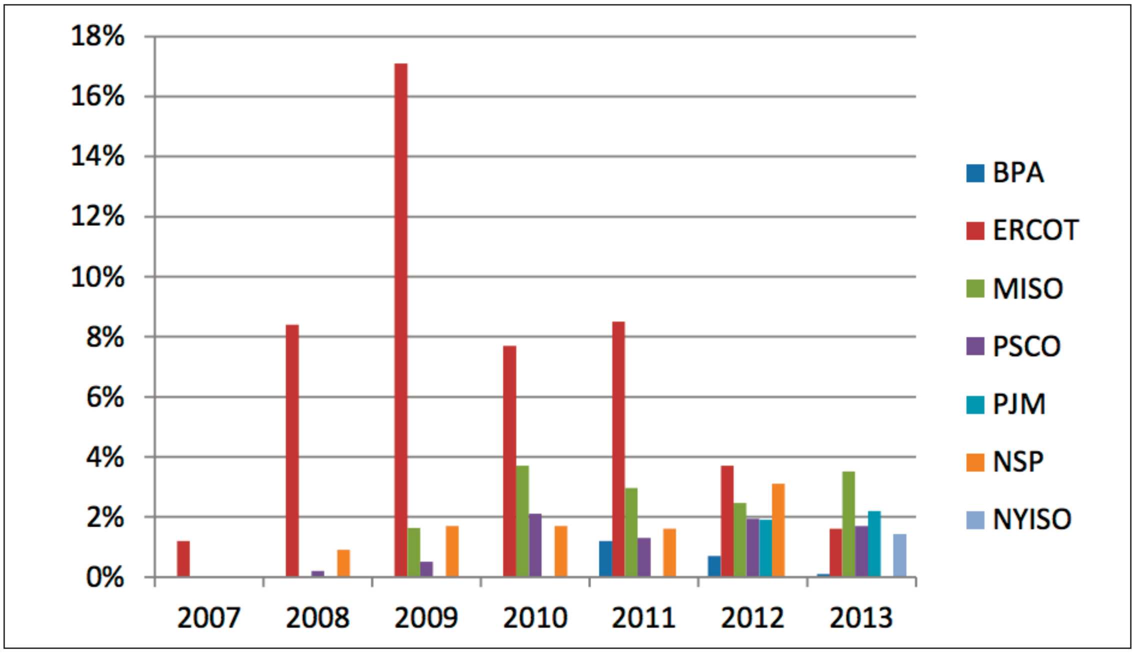


FIGURE 6: Curtailment as Fraction of Wind Generation *(Source: NREL curtailment report)*

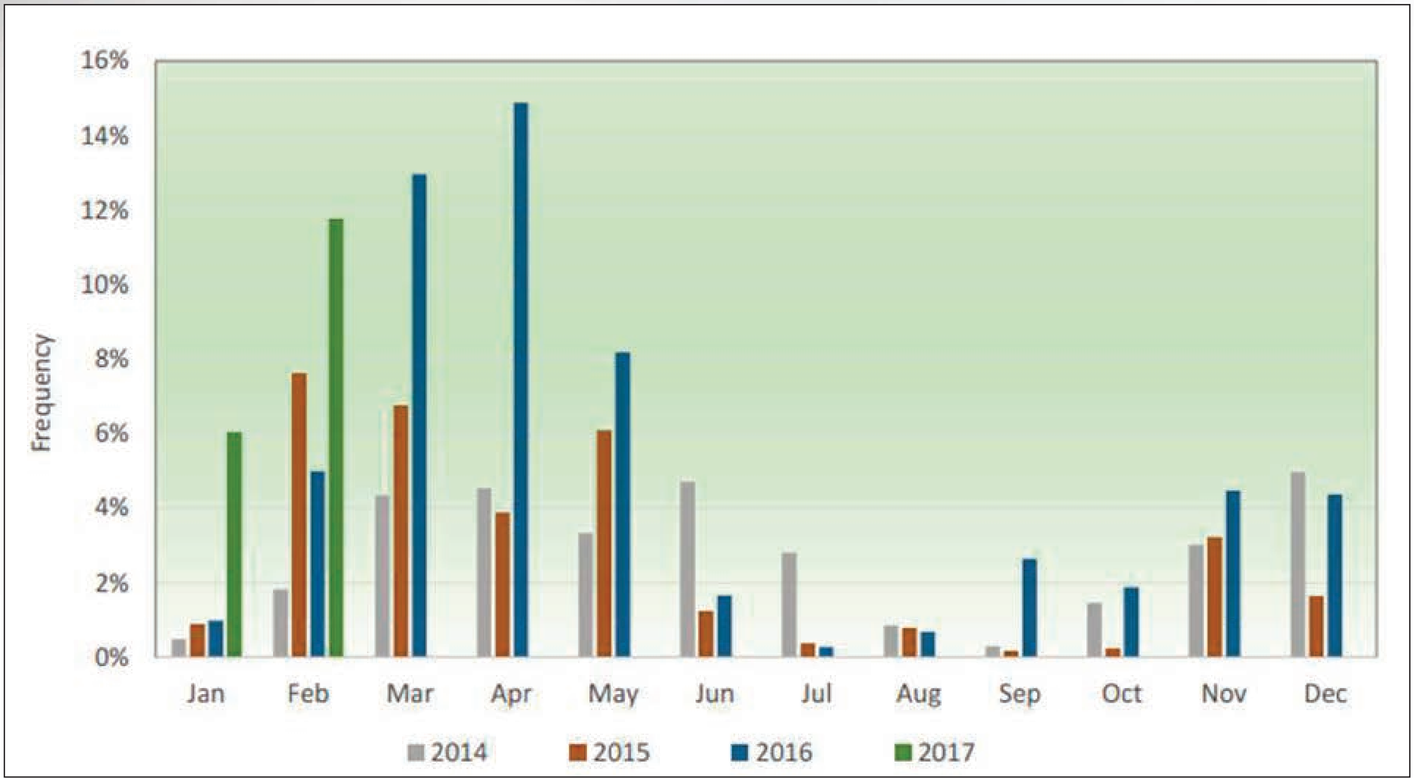


FIGURE 7: Frequency of Negative System Prices Has Steadily Increased Year Over Year *(Source: CAISO March 2017 Market Report)*

Some repairs can be costlier because they cannot be done up-tower, so require renting large cranes to lift new equipment to the top of the tower.

Figure 7 shows the increasing frequency of negative prices in California, which primarily is driven by excess solar generation, but in the past was partially caused by excess wind generation as well.

Operation & Maintenance

Like all generation equipment, wind turbines have ongoing costs for operations and maintenance (O&M). They require regular lubrication of gear boxes and bearings, air and oil filter replacement, and checking bolt torque. This work can be completed up-tower, meaning that technicians climb to the top of the tower to do the work. Costs are relatively low for routine maintenance, in part because cranes are typically not needed.[7]

Unplanned repairs may include replacing gearbox, electrical, and storm-damaged components. These repairs can be costlier, because they cannot be done up-tower, meaning that repair costs include rental of large cranes to lift new equipment to the top of the tower. Large crane rentals in remote areas may cost $150,000 to $300,000 or more, or 5 to 10 percent of the original cost of the wind turbine, and may cause long delays due to crane availability and weather.[8] "Failing to notice a $1,000 bearing problem can lead to a $100,000 gearbox replacement, a $50,000 generator rewind, and a $75,000 crane hire."[9]

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7 http://www.power-eng.com/articles/print/volume-117/issue-5/features/wind-turbine-lubrication-and-maintenance-protecting-investments-.html

8 Depending on the wind farm location and repair, a crane hire can cost up to $400,000, as per GE staff presentation to NRECA, May 2017, Greenville, SC.

9 http://www.windpowermonthly.com/article/989458/turbine-servicing---act-warranty

TABLE 1: Capacity-Weighted Average O&M Costs from 2000 – 2015

Construction Date	O&M Costs ($/MWh)	Sample Size
1980s	$35	24
1990s	$24	37
2000s	$10	65
Post-2010	$9	28

Source: Bolinger & Wiser, 2016

On-site upgrades, called repowering, allow existing infrastructure at wind farms to take advantage of industry advances that have occurred since installation.

Two common concerns are about sound and collision risks to birds and bats.

Operation and maintenance costs are trending downward. Table 1 shows the drop in O&M costs over time from a sample of 154 US wind farms, the earliest constructed in 1982.

"This drop in O&M costs may be due to a combination of at least two factors: (1) O&M costs generally increase as turbines age, component failures become more common, and manufacturer warranties expire; and (2) projects installed more recently, with larger turbines and more sophisticated designs, may experience lower overall O&M costs on a per-MWh basis" (Bolinger & Wiser, 2016, p. 58-59).

Repowering

As early wind farms, developed nearly two decades ago, near end-of-life — or when a developer's PTC runs out after ten years of operation — manufacturers now offer on-site upgrades to extend life and increase energy production. This is called *repowering*, and it allows existing infrastructure at wind farms to take advantage of industry advances that have occurred since installation. Repower services may include:

- Inspection of tower, foundation, and electrical system
- Installation of longer blades
- Replacement of hub, pitch system, gearbox components, and nacelle
- Upgrade or replacement of control systems
- Re-use of site only — replacement of all equipment, including towers and foundations

In 2017, GE repowered a 300-turbine NextEra wind farm. According to the manufacturer, "Repowering can increase fleet output by up to 25 percent and add an additional 20 years to turbine life from the time of the repower."[10] Vestas, Siemens Gamesa, and other manufactures also began major repower projects in the U.S. and around the world in recent years with similar claims for increased Annual Energy Production (AEP) and lifetimes. Generally, turbines with larger rotors yield greater AEP. In just the last seven years, blade lengths have grown by about 30 percent (MAKE, 2016). This nearly doubles the swept area, and is one reason for AEP gains when older sites are repowered with modern-day turbines.

Repowering is also a way to extend the PTC for an additional ten years, as long as the project starts before the PTC fully phases out in 2020. Assuming repowering costs $1,000/kW, increases annual energy production by 25 percent, extends the life by 20 years, is financed with 100 percent low cost electric cooperative debt financing and 2.1 percent cost of money, and requires $37/kW for fixed O&M; then the levelized cost of electricity would be a low $23/MWh (without including the PTC) plus an extension of the PTC if the project is a joint venture with a taxable entity (resulting in a net cost today of nearly $5/MWh).

ENVIRONMENTAL IMPACTS

All power plants and large-scale developments have impacts on the environments that host them, and wind farms are no exception. Wind farm siting requirements attempt to reduce or mitigate risks to plants, animals, and humans in surrounding areas, and numerous state, fed-

[10] http://www.genewsroom.com/press-releases/ge-adds-value-us-wind-turbine-industry-its-repower-offering-283781

eral, non-profit, industry, and academic organizations are pursuing research to better understand impacts of wind energy developments. Two concerns commonly expressed are about sound and collision risks to birds and bats.

Sound

Wind turbines make noise. In addition to the sound of wind passing over the blades (aerodynamic noise), components like generators and gearboxes produce mechanical noise. Some people who reside near wind farms have complained that this noise is annoying. Others have claimed that low-frequency, or *infra sound*, wind turbine noise disturbs their sleep and negatively impacts their health in other ways.[11] Many peer-reviewed research projects have been conducted to determine impacts of wind turbine noise on human health; so far, there is no substantive evidence of this. (DOE, 2015; McCunney, Mundt, Colby, Dobie, Kaliski & Blais, 2014; Michaud, Feder, Keith, Voicescu, Marro, Than, et al., 2016).

However, it is prudent to build wind farms as far away as possible from residential areas.

TABLE 2: Estimated Annual Bird Mortality Rates From Collisions with Anthropogenic Sources (U.S.)

Structure	Average Mortality Rates (million birds/year)
Wind turbines	0.1 – 0.7
Communications and other towers*	6.6
Power lines**	9 – 70
Automobiles	89 – 440
Buildings	300 – 1,000

* range not provided
** collisions & electrocutions

Source: Loss, Will & Marra, 2015

Current wind farm siting requirements aim to locate wind farms far enough from human populations, so that there is no noise disturbance. Modern wind farms also have monitoring equipment on their perimeters to measure emitted noise levels, and can operate in noise reduction modes with minimal impact on efficiency. In addition, manufacturers are adding serrations and airfoils to blade tips to reduce sound.[12]

Birds and Bats

There is interest both inside and outside the wind industry to understand the risk of wind energy development to birds and bats, and to develop effective solutions. This is a heavily researched topic where lots of data have been collected and more research is needed. Numerous governmental, scientific, and non-profit agencies, as well as the wind industry, are actively conducting research to accurately assess risk and to devise effective strategies to mitigate that risk.

While avian and other non-flying species may be affected by site disturbances, like new roads and turbine pads, the area that has captured the most public and scientific interest are instances of birds and bats colliding in flight with towers and blades. To date, scientists have conducted studies of bird and bat collisions at more than 100 wind farms. These studies are ongoing and often yield wide ranges of results (DOE, 2015). Multiple estimates indicate that birds killed by wind turbine collisions pale in comparison with other human-made sources (see Table 2).

The American Wind Wildlife Institute (AWWI), an independent nonprofit that works with the wind industry and conservation and science organizations to understand the risk of wind energy

[11] http://oto2.wustl.edu/cochlea/wind.html

[12] Information presented by GE staff, May 2017, to NRECA in Greenville, SC

development to wildlife and develop solutions, compiles and annually updates a very useful summary of recent, peer-reviewed research on the impacts of land-based wind power on wildlife in North America (AWWI, 2017).

Some key themes are:

- **Small birds:** Fatalities of common, small birds that are less than 31 centimeters long, known as *passerines,* are likely between 3 to 6 per MW per year. Best estimates of the cumulative impact of this mortality indicate that, for most species of passerines, about 0.02 percent of the population are affected, which suggests that overall population of the species is not affected.

- **Raptors:** It is not yet known if wind turbines affect populations of some raptors. Raptors, like hawks and eagles, are far less abundant than smaller birds and comprise a larger percentage of bird fatalities at wind energy facilities than other human-made structures. At California's Altamont Pass Wind Resource Area, one of the earliest wind developments in the U.S., raptor fatalities were higher than expected. However, fatalities at this site may be declining as a result of repowering. Smaller, lower capacity turbines are replaced with taller, higher capacity turbines that complete fewer rotations per minute and have tubular support towers that do not offer perching sites for raptors, both of which may be factors in the reduction in fatalities.

- **Bats:** Bat fatalities from wind turbine collisions is an area of active research; it is unknown if the overall population of any bat species is affected by collision mortality. Population size is not known for many bat species.

- **Mitigation:** Strategies to reduce bird and bat fatalities include siting wind farms with consideration for migratory patterns (using, for example, the U.S. Fish and Wildlife Service's Land-based Wind Energy Guidelines), and locating turbines away from landscape features known to attract raptors and bats. Furthermore, curtailing turbine operation at low wind speeds significantly reduces bat fatalities, and shutting down specific turbines where raptor collision risk is high may also be effective. Other strategies under development include the use of technologies that detect key species, and deter or curtail operations when key species are present.

Electric cooperatives interested in reducing wildlife impacts of wind energy are encouraged to visit the AWWI website (**awwi.org**) or contact AWWI (**info@awwi.org**).

OFF-SHORE WIND

Off-shore wind turbines are taller than on-shore models, have longer rotor diameters, and produce two to three times more electric power — capacity ranges from 3 MW to more than 9.5 MW from the three main manufacturers, and rotor diameter from 112 to 164 meters.[13,14,15] See **Figure 8.**

Off-shore wind turbines can have fixed or floating bases. Costs range widely depending in part on distance from shore and water depth. A 2016 report from National Renewable Energy Laboratory showed LCOE estimates for a 4.14 MW fixed-based wind turbine at \$181/MWh, and \$229/MWh for the same capacity floating base model. O&M costs were \$49.6/MWh and \$38.4/MWh, respectively (Moné, et al., 2017).

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[13] https://www.gerenewableenergy.com/wind-energy/turbines/offshore-turbine-haliade.html

[14] http://www.mhivestasoffshore.com/innovations

[15] https://www.siemens.com/global/en/home/markets/wind/offshore.html

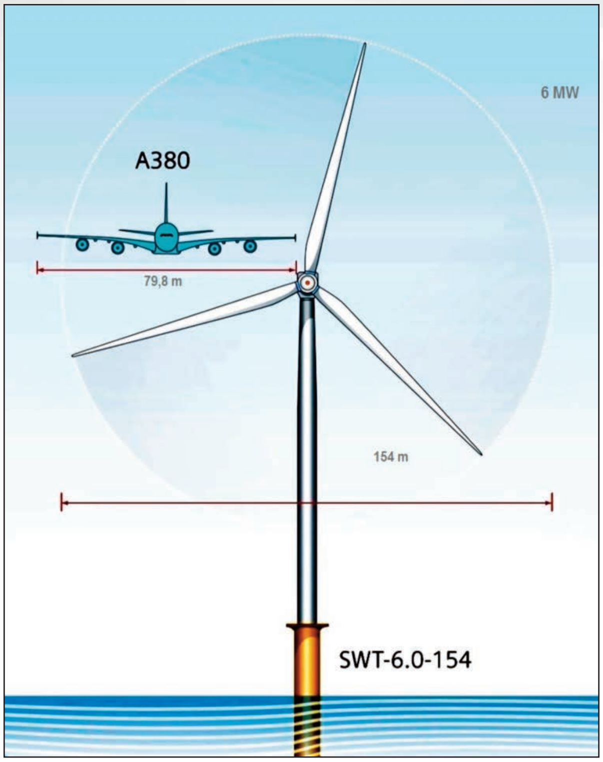

FIGURE 8: Siemens 6 MW Offshore Wind Turbine Compared to Airbus 380 *(Source: Siemens 2016)*

The cost for off-shore wind turbines is currently multiple times that of on-shore; but, technology is improving and costs are expected to decrease significantly over time. It must be pointed out that off-shore wind turbines provide power and energy that is consistent with a typical load shape, providing peak capacity during the day and late afternoon — when systems need power the most.

NEXT GENERATION WIND TECHNOLOGIES

NRECA is watching the wind energy space and keeping an eye out for promising new technologies and opportunities, such as the use of high-altitude drones and energy kites for harvesting wind energy. We will also explore innovative offerings from manufacturers, such as GE's Wind Integrated Solar Energy (WiSE) technology, which is scheduled to be commercially deployed by the end of 2017.[16] WiSE eliminates the solar inverter with a hybrid converter between the wind and solar PV to source the AC and DC power together and thus, effectively utilize a common converter system. The solar PV balance of plant is essentially eliminated, and integrated SCADA is used to monitor and control both the wind and solar systems. The end result is a reduction in capital costs of 10 to 15 percent for the two systems and adding 8 to 9 percent annual energy production of the wind generator.

CONCLUSION

Wind energy is now a mature technology, and recent advances are lowering development and O&M costs, and increasing energy production. Advanced sensors and controls are enabling lighter-weight components, reductions in costly repairs, and better integration with the grid. Because of this, utilities continue to add more wind into their generation mixes (see **Figure 9**).

The phase-out of the PTC by 2020 means that electric cooperatives not located in energy markets (like SPP, ERCOT, MISO, etc.) may find it more cost-effective to own their own wind farms compared to purchasing wind energy from developers. However, those co-ops located in energy markets will need to continue to purchase wind energy from PPAs or form joint ventures/Limited Liability Partnerships with taxable entities to utilize the PTC to be able to compete in markets where the PTC causes low or even negative energy prices. Note the PTC subsidy dramatically impacts the LMP in energy markets and thus, any wind farm's capacity factor (and demand factor) in energy markets without a PTC will be reduced due to the low

[16] http://www.genewsroom.com/press-releases/ge-renewable-energy-equip-first-commercial-us-integrated-solar-wind-hybrid-project

LMP prices (possibly reducing a capacity factor from 50 percent down to capacity factors in the 30s or 40s due to low market LMPs).

For the entire NRECA *TechSurveillance* article series on wind generation and its impact on cooperatives, please visit **cooperative.com**. ■

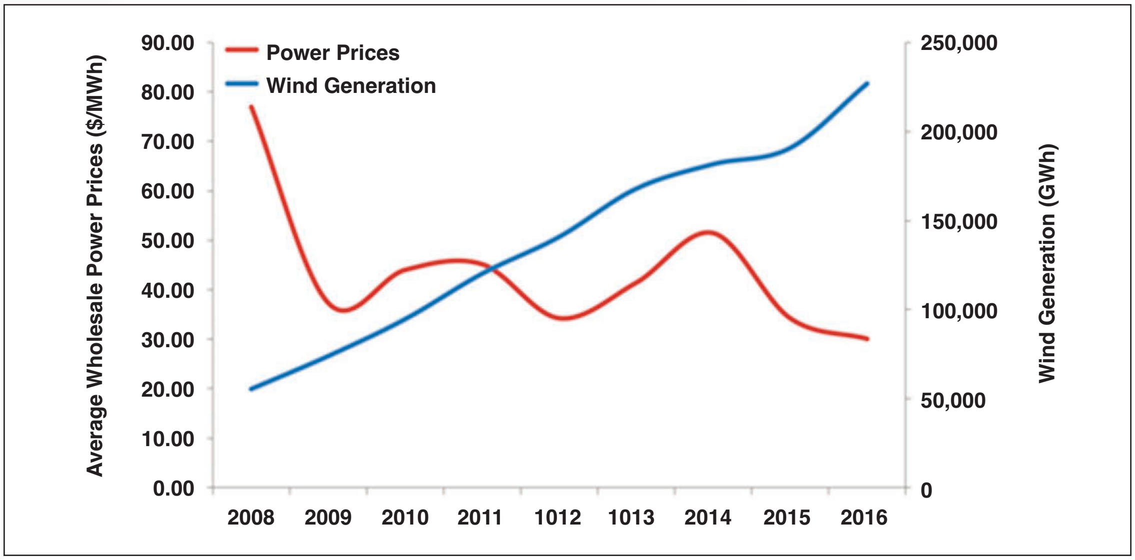

FIGURE 9: Average U.S. Wholesale Power Prices Down More Than 60% as Market Share of Low-Cost Wind Power Increases Almost Five-Fold *(Source: Renewable Energy World, 2017)*

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About the Author

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