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ENERGY EFFICIENCY &
RENEWABLE ENERGY

# 2018 Distributed Wind Market Report

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# Acronyms

| | |
|---|---|
| AWEA | American Wind Energy Association |
| CIP | Competitiveness Improvement Project |
| DOE | U.S. Department of Energy |
| EIA | Energy Information Administration |
| FIT | feed-in tariff |
| GE | General Electric |
| GW | gigawatt(s) |
| IEA | International Energy Agency |
| IEC | International Electrotechnical Commission |
| ICC-SWCC | International Code Council-Small Wind Certification Council |
| IRS | Internal Revenue Service |
| ITC | investment tax credit |
| kV | kilovolt(s) |
| kWh | kilowatt hour(s) |
| LCOE | levelized cost of energy |
| $m^2$ | square meter(s) |
| MW | megawatt(s) |
| NPS | Northern Power Systems |
| NREL | National Renewable Energy Laboratory |
| NYSERDA | New York State Energy Research and Development Authority |
| O&M | operations and maintenance |
| PNNL | Pacific Northwest National Laboratory |
| PV | photovoltaic |
| REAP | Rural Energy for America Program |
| USDA | U.S. Department of Agriculture |
| VAWT | vertical-axis wind turbine |
| W | watt(s) |

# Executive Summary

**Cumulative U.S. distributed wind capacity installed from 2003 to 2018 now stands at 1,127 megawatts (MW) from over 83,000 wind turbines** across all 50 states, Puerto Rico, the U.S. Virgin Islands, and Guam. Distributed wind systems are distributed energy resources connected at the distribution level of the electricity system or in microgrid or off-grid applications.

**In 2018, 12 states added 50.5 MW of new distributed wind capacity representing 2,684 units and $226 million in investment.** A total of 21 MW of this new capacity was installed in Rhode Island by a single developer for multiple customers. This is illustrative of a trend, in which a few project developers using large-scale turbines work almost exclusively in specific states rather than nationwide, resulting in annual distributed wind capacity additions concentrated in a few states.

**Of the 50.5 MW, 47.4 MW came from distributed wind projects using large-scale turbines (greater than 1 MW in size),** 1.6 MW came from projects using mid-size turbines (101 kilowatts [kW] to 1 MW in size), and 1.5 MW came from projects using small wind turbines (up through 100 kW in size).

**The 47.4 MW from projects using turbines greater than 1 MW is down 39% from the 78 MW documented in 2017, but fits the slightly up and down pattern of the past few years** during which distributed wind capacity from projects using turbines greater than 1 MW was 43 MW in 2016, 21 MW in 2015, and 57.5 MW in 2014. The development cycle of a few project developers using large-scale turbines likely influences this slightly up and down pattern of installed capacity from projects using turbines greater than 1 MW.

**Projects using mid-size turbines continue to represent a small part of the distributed wind market.** The 1.6 MW of capacity from projects using mid-size turbines is down 60% from 4 MW in 2017, but installed capacity from mid-size turbines has been under 5 MW annually since 2013.

**The average nameplate capacity of turbines greater than 100 kW in distributed wind projects has increased over the years.** In 2003, the average turbine capacity used in distributed wind projects with turbines greater than 100 kW in size was 1.1 MW. In 2018, the average capacity size was almost double that—2.1 MW. This trend mirrors the increase in turbine capacity size used for all land-based wind projects.

**In 2018, commercial and industrial projects represented almost 29% of total project capacity documented, up from 9% in 2017 and 5% in 2016.** While the number of commercial and industrial projects have been fairly steady the past few years, the larger turbine sizes used in these projects have increased the capacities of the projects as well.

**Along with commercial and industrial projects, distributed wind for utility customers also represents a large part of the documented installed capacity, while capacity installed by agricultural and residential customers is declining.** A total of 47% of capacity in 2018 was for utility customers compared to 78% in 2017. In 2018, agricultural and residential projects accounted for 1% of the documented capacity, compared to just under 3% in 2017. As agricultural and residential customers predominantly use small wind turbines, this decrease mirrors the decrease in small wind sales.

**A total of 1.5 MW of small wind was deployed in the United States in 2018, representing 2,661 units and $8.2 million in investment.** Driven by changing federal and state policy environments and continued competition from low-cost solar photovoltaic technology, this 12% drop in capacity from 2017 continues the downward trend for small wind capacity of recent years. Small wind deployment was 1.7 MW in 2017, 2.4 MW in 2016, and 4.3 MW in 2015.

**The less than 1-kW turbine size segment is contributing an increasingly large percentage of both the total deployed units and the total deployed capacity for small wind projects.** Sales of turbines with capacity less than 1 kW have remained fairly level year to year, but as overall small wind capacity deployment has decreased annually and there are fewer sales in the other size segments, the less than 1-kW turbines now account for a larger share of the small wind market. In 2012, turbines less than 1-kW in size accounted for 7% of the deployed small wind capacity and 70% of the units. In 2018, the less than 1-kW turbine size segment accounted for 47% of the deployed small wind capacity and 99% of the units.

**Fluctuating policy environments in foreign markets also impact U.S. small wind manufacturers.** The primary markets for U.S. small wind exports over the years have been the United Kingdom, Italy, and Japan because of feed-in tariff programs in those countries. However, all of these programs have been changed and there may be more changes in the future; therefore, the attractiveness of the market for U.S. small wind manufacturers may be impacted.

**Small wind exports from U.S.-based manufacturers dropped significantly to just under 1 MW in 2018, representing an investment of $4.6 million, driven primarily by changes in the feed-in tariff programs of export countries.** This is down from 5.5 MW and a $42 million investment in 2017, 10.3 MW and $62 million in 2016, and a peak of 21.5 MW and $122 million in 2015.

**The combined value of U.S. Department of Agriculture Rural Energy for America Program grants and state rebates, production-based incentives, and production tax credits given to distributed wind projects in 2018 was $8.9 million.** This is down from $13.3 million in 2017, $12.8 million in 2016, and $10.6 million in 2015, and significantly lower than the peak of $100 million in 2012. The decline reflects both fewer state incentives being paid and the lack of Section 1603 payments. The U.S. Treasury reported a peak of $63 million of Section 1603 grant payments in 2012, but no new grants were reported in 2018, signaling the likely end of these payments.

**A total of ten different small wind turbine models are certified to the American Wind Energy Association standard or International Electrotechnical Commission standards as of June 2019.** Three new turbine models completed the certification process in 2019, but the total number of certified turbine models is down (i.e., from 16 in May 2018) because many manufacturers have let their certifications expire. Certification requirements are increasingly common in the global market. Certification is consistent with industry and U.S. Department of Energy goals to promote the use of proven technology; improve the competitiveness of small wind; and increase consumer, government agency, and financial institution confidence and interest in distributed wind.

**The average per-kilowatt cost of distributed wind projects using turbines greater than 100 kW installed in the United States in 2018 was $4,437/kW** based on 11 projects representing 28.9 MW. This is an increase from $3,014/kW in 2017 (40.1 MW and 6 projects). The two average cost values are driven by different developers with multiple project sites that biased the sample size each year. Small wind project-specific installed costs, as reported by installers and state and federal agencies, have increased since 2009 and have been fairly flat since 2014.

**For a sample of projects, the small wind average levelized cost of energy (LCOE) after incentives was 23¢/kilowatt hour (kWh), the mid-size turbine project average LCOE after incentives was 14¢/kWh, and the large-scale turbine project average LCOE after incentives was 5¢/kWh.** The small wind three-year average capacity factor was 17%, the mid-size turbine project three-year average capacity factor was 25%, and the large-scale turbine project three-year average capacity factor was 31%. In general, the higher the capacity factor, the lower the LCOE.

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# 1 Introduction

The U.S. Department of Energy's (DOE) annual Distributed Wind Market Report provides stakeholders with market statistics and analyses along with insights into its trends and characteristics.

Distributed wind systems are distributed energy resources connected at the distribution level of the electricity system or in microgrid or off-grid applications.[1] Distributed wind systems can range from a less than 1 kilowatt (kW)[2] off-grid wind turbine at a remote cabin or oil and gas platform, to a 10-kW wind turbine at a home or farm, to several multi-megawatt wind turbines at a university campus, at a manufacturing facility, or connected to the distribution system of a local utility.

Individuals, businesses, and communities install distributed wind systems to offset retail power costs or secure long-term power cost certainty, support grid operations and local loads, and electrify remote locations and assets not connected to a centralized grid. Depending on its application, distributed wind can either provide grid independence or potentially improve system resilience, reliability, and flexibility.

## 1.1 Purpose of Report

The annual Distributed Wind Market Report is part of DOE's Wind Energy Technologies Office distributed wind portfolio. The objective of the portfolio work is to enable wind technologies as distributed energy resources to contribute maximum economic and system benefit to energy systems now and in the future.

To that end, the Distributed Wind Market Report analyzes distributed wind projects of all sizes and details the U.S. small wind market. It is valuable to break out the small wind market for comparison to global markets and because other market reports concentrate only on U.S. wind projects using turbines greater than 100 kW. By providing a comprehensive overview of the distributed wind market, this report can help guide future investments and decisions by industry, utilities, federal and state agencies, and other interested parties. This report provides key information to help stakeholders understand and access market opportunities and inform distributed wind industry research and development needs.

## 1.2 Wind Turbine Size Classification

The distributed wind market includes wind turbines and projects of many sizes. When appropriate, this report breaks the market into the following three turbine size segments:

- Wind turbines up through 100 kW (in nominal, or nameplate, capacity)—referred to in this report as "small wind"
- Mid-size wind turbines 101 kW to 1 MW
- Large-scale wind turbines greater than 1 MW.

The U.S. Internal Revenue Service (IRS) also defines small wind as up through 100 kW for the purpose of federal investment tax credit (ITC) eligibility (see Section 4.1.2).

[1] The term off-grid can apply to a stand-alone power system (i.e., a wind system that directly serves onsite loads) or an isolated microgrid (i.e., a microgrid that is never connected to a local distribution grid). Future reports may expand on these terminology variations. An isolated microgrid may include a wind turbine system and battery backup or other energy storage because it is not connected to a local distribution grid that could provide backup energy. Grid-connected distributed wind systems can be connected to the distribution grid or behind the meter (i.e., on the customer side of the meter). Virtual (or remote) net metering allows a customer to receive net metering credit from a remote renewable energy system as if it was located behind the customer's own meter.

[2] 1 gigawatt (GW) = 1,000 megawatt (MW); 1 MW = 1,000 kilowatt (kW); 1 kW = 1,000 watt (W)

The nominal, or nameplate, capacity of a wind turbine is what manufacturers use to describe, or name, their wind turbine models. For projects using turbines greater than 100 kW, the project's total nominal power capacity is used in the cost per kilowatt and related analyses. For small wind, this report uses the total rated power capacity of the project in the cost per kilowatt and related analyses. A certified small wind turbine's rated capacity is its power output at 11 meters per second (m/s) per its power curve as tested to the American Wind Energy Association (AWEA) 9.1-2009 Standard or the International Electrotechnical Commission (IEC) 61400-12-1 Standard. For turbines that are not certified, the power output at 11 m/s is assigned as the turbine's rated, or referenced, capacity. The manufacturer's nominal, or nameplate, capacity of a small wind turbine may be higher than the rated capacity because it is based on the power output at a higher wind speed. Rated capacities for the small wind turbine models included in this report are listed in Appendix B.

## 1.3 Data Collection and Analysis Methodologies

To produce this report, DOE's Pacific Northwest National Laboratory (PNNL) issued data requests to turbine manufacturers and suppliers, developers, installers, operations and maintenance (O&M) providers, state and federal agencies, utilities, and other stakeholders. A project dataset was created to capture all projects installed in 2018 identified through the data request process.

For distributed wind projects using turbines greater than 100 kW, the PNNL team reviewed the AWEA database and other sources (e.g., the Federal Aviation Administration database) and assessed each project to determine if it met DOE's definition of distributed wind and should, therefore, be included in the distributed wind project dataset. Additional data sources (e.g., U.S. Energy Information Administration [EIA]) are also consulted to supplement project records.

Small wind project records from manufacturers and suppliers, O&M providers, utilities, and agencies obtained through the data request process also were added to the project dataset. However, PNNL cannot obtain project-level records for many of the 2018 small wind units sold, such as off-grid turbine units purchased from dealers, so those units are not included in the project dataset, but are included in the small wind sales dataset described below.

The project dataset is used to make year-to-year comparisons, allocate capacity values across states, analyze installed costs, identify incentive funding levels, and characterize distributed wind customers, types of turbines and towers, and project locations (i.e., grid-tied or off-grid and behind-the-meter or on the local distribution grid).

PNNL also created a separate small wind sales dataset based on manufacturers' sales reports.[3] This study reports small wind capacity and units deployed, domestically and abroad, for the same calendar year as the reported sales by the manufacturers and suppliers. Appendix B details the data collection process and analysis methodology.

[3] Most manufacturers report precise units sold, but at least one manufacturer provides estimated units sold because the company's less than 1-kW size units are shipped in bulk to distributors.

# 2 U.S. Distributed Wind Deployment

From 2003 through 2018, over 83,000 wind turbines were deployed in distributed applications across all 50 states, Puerto Rico, the U.S. Virgin Islands, and Guam, totaling 1,127 MW in cumulative capacity (Figure 1).[4] In 2018, 12 states added 50.5 MW of new distributed wind capacity representing 2,684 units and $226 million in investment.[5] This is down from 21 states adding 83.7 MW of new distributed wind capacity, representing 3,311 units and $274 million in investment in 2017.

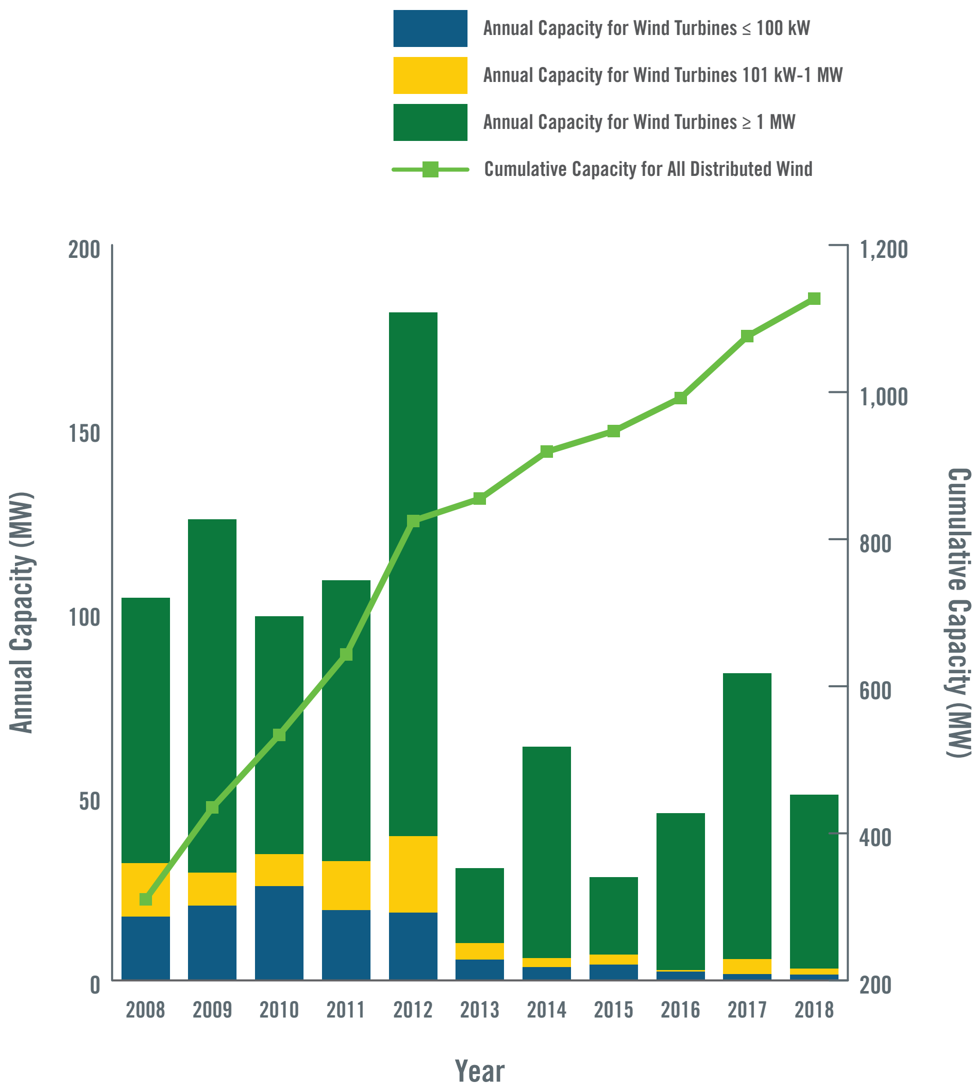


**Figure 1.** U.S. distributed wind capacity

[4] The data presented in the figures are provided in an accompanying data file available for download at https://www.energy.gov/eere/wind/downloads/2018-distributed-wind-market-report.

[5] All dollar values are nominal unless otherwise noted. Annual and cumulative capacity values are based on nameplate turbine capacity sizes.

## 2.1 Top States for Distributed Wind: Annual and Cumulative Capacity

New distributed wind projects were documented in 12 states in 2018 (Figure 2) and have been documented in all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam since 2003 (Figure 3).

Rhode Island, Ohio, and Nebraska led the United States in new distributed wind power capacity in 2018 as a result of large-scale turbine projects. The 21 MW of distributed wind that Green Development, LLC added to its portfolio in Rhode Island in 2018 accounts for almost half of the documented 2018 distributed wind capacity and almost doubles Rhode Island's cumulative distributed wind capacity. These installations, and Green Development's 2016 projects, were enabled by both Rhode Island's expansion of its net metering policy in 2016 to include virtual net metering and the creation of the tariff-based incentive Renewable Energy Growth Program in 2014 (DSIRE 2017; DSIRE 2018). For example, the energy from one of the 2018 projects is sold to the state convention center through a virtual net metering agreement. Prior to 2016, there were no documented distributed wind projects in Rhode Island (Orrell et al. 2017).

New York and Alaska had the most reported small wind projects in 2018. With the New York State Energy Research and Development Authority (NYSERDA) small wind turbine incentive program, New York has been a leader in small wind capacity deployment in past years. The state's small wind incentive program ended December 31, 2018, but was reinstated on April 1, 2019, through at least the end of 2019 at the request of state stakeholders. Many projects are in the queue to receive the incentive, but their installations were not completed by the end of 2018 so were not reported to be included in this report.

Figure 3 shows both the 2018 capacity additions and the cumulative capacity for each state. While, there is some amount of distributed wind in every state, annual installations vary greatly across the states, as also illustrated in Figure 4 and Figure 5. Figure 4 shows the states with cumulative distributed wind capacities greater than 20 MW. Figure 5 shows the states with cumulative small wind capacities greater than 2 MW.

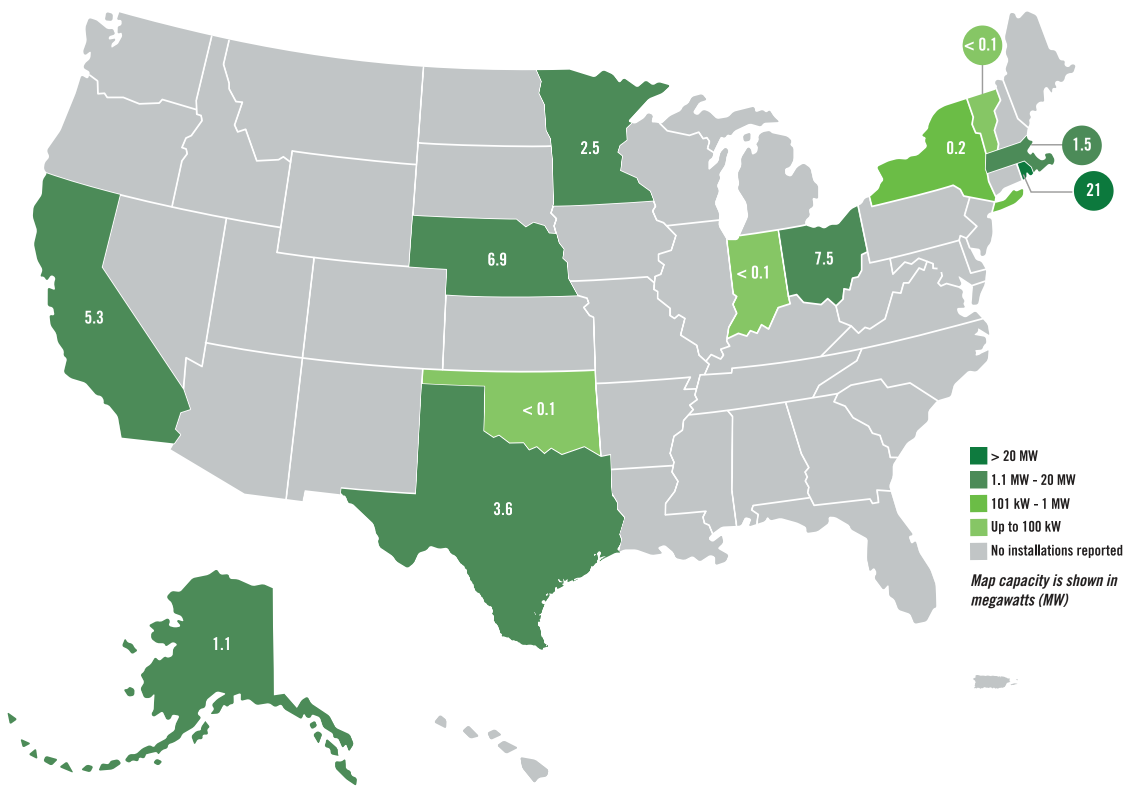


**Figure 2.** 2018 U.S. distributed wind capacity additions by state

While Texas, Iowa, and Minnesota remain the top three states for overall distributed wind capacity, and Iowa, Nevada, and Alaska are the top three states for small wind capacity, there were no documented projects in Iowa or Nevada in 2018. In contrast, Iowa had 63.5 MW of new capacity additions in 2017.[6] This variation can be partly attributed to project development cycles. A few project developers using large-scale turbines, namely One Energy Enterprises LLC (One Energy) in Ohio; Green Development, LLC in Rhode Island; Foundation Windpower in California; and Optimum Renewables in Iowa, may not install new projects every year as each project make take multiple years to develop. And because each company works almost exclusively in one state rather than nationally, annual distributed wind capacity additions can be concentrated in a few states.

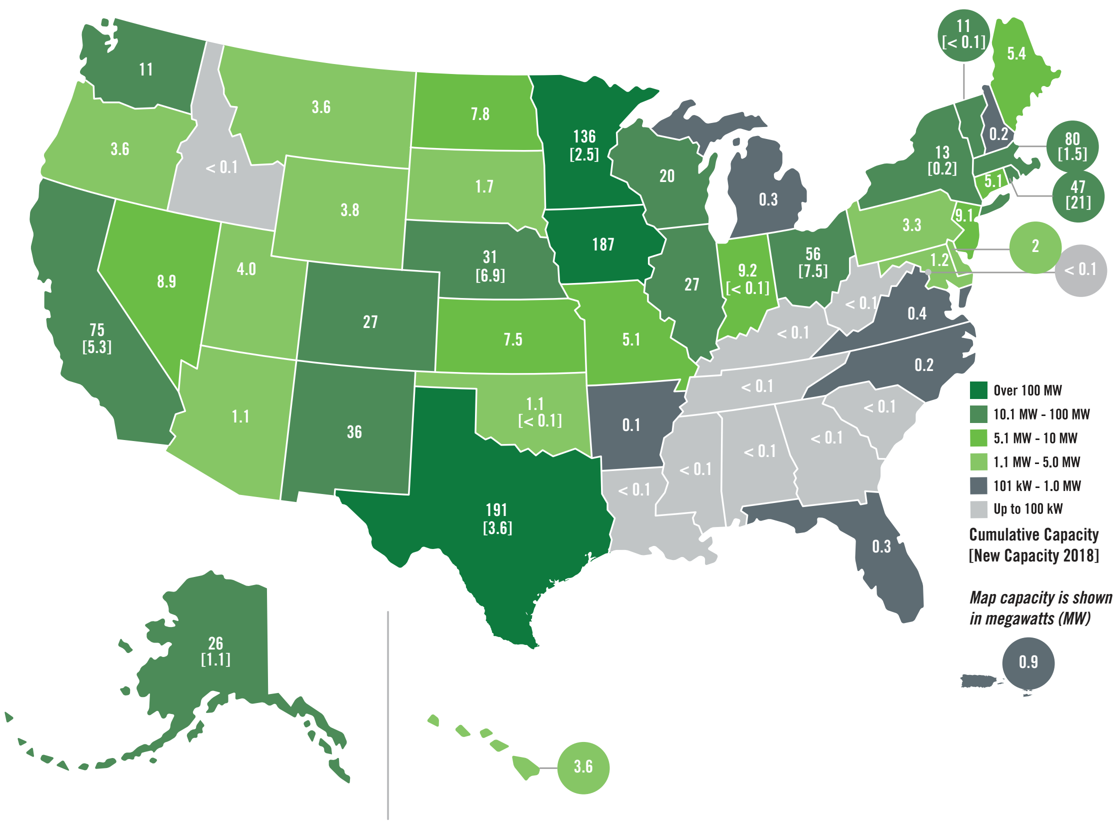


**Figure 3.** 2003–2018 cumulative U.S. distributed wind capacity by state

[6]One project of 6 MW was decommissioned in 2018.

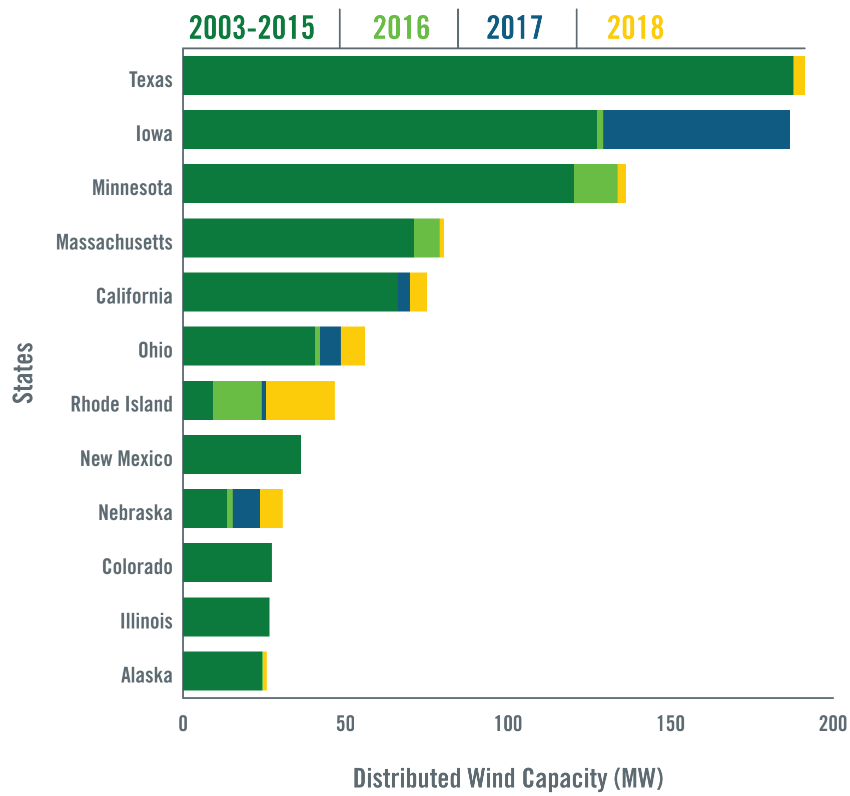


**Figure 4.** States with distributed wind capacity greater than 20 MW, 2003–2018

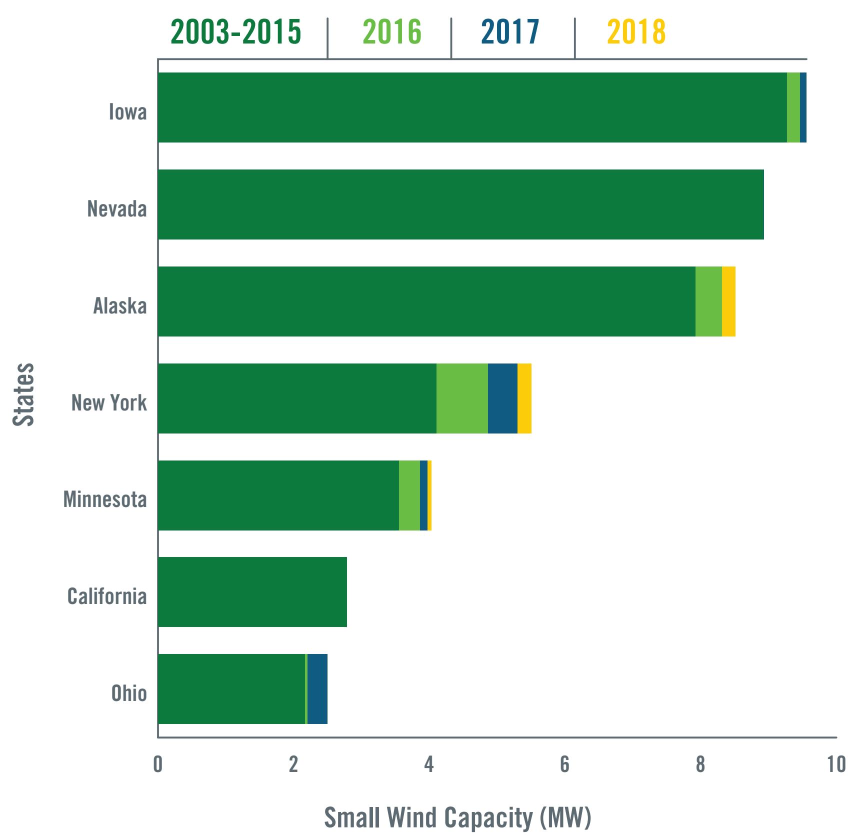


**Figure 5.** States with small wind capacity greater than 2 MW, 2003–2018

# 3 U.S. Distributed Wind Projects, Sales, and Exports

Of the 50.5 MW of distributed wind added in 2018, 47.4 MW came from projects using turbines greater than 1 MW, 1.6 MW came from mid-size turbines, and 1.5 MW came from small wind.

## 3.1 Mid-Size and Large-Scale Turbines

A total of 47.4 MW of the 2018 distributed wind capacity came from projects using turbines greater than 1 MW and 1.6 MW came from mid-size turbines. The total of 49 MW represents $218 million in investment.

The 47.4 MW from projects using turbines greater than 1 MW is down 39% from the 78 MW documented in 2017, but fits the slightly up and down pattern of the past few years where distributed wind capacity from projects using turbines greater than 1 MW was 43 MW in 2016, 21 MW in 2015 and 57.5 MW in 2014.

This sustained activity can be attributed to the increase in distributed wind projects using both large-scale turbines (greater than 1 MW) and larger capacity turbines within this turbine size class. For example, Green Development LLC used 3-MW Vensys wind turbines for its various 2018 projects, but 1.5-MW turbines for its 2016 projects.

Projects using mid-size turbines continue to represent a small part of the distributed wind market. The 1.6 MW of capacity from projects using mid-size turbines is down 60% from 4 MW in 2017, but installed capacity from mid-size turbines has been under 5 MW annually since 2013.

The mid-size and large-scale turbine markets rely on imports. Of the five manufacturers of turbines greater than 100 kW with distributed wind projects deployed in 2018, one is U.S.-based (i.e., General Electric [GE] Renewable Energy), three are importers (i.e., EWT Americas [Netherlands], Goldwind [China], and Vensys [Germany]), and one is a refurbished Zond turbine model of unknown origin.

Manufacturer representation in U.S. distributed wind projects changes from year to year. For example, Aeronautica (United States), Free Breeze (Canada), HZ Windpower (China), and Nordex (Germany) had turbine models used in recorded distributed wind projects in 2017, but not in 2018 (or 2016 or 2015).

On the other hand, some manufacturers are consistently represented in distributed wind projects. GE Renewable Energy has been the only consistent U.S.-based manufacturer of large-scale turbines used in distributed wind projects for the past seven years and is the turbine provider for Foundation Windpower in California. Goldwind is the sole turbine supplier for One Energy, a distributed wind project developer based in Ohio. And Green Development, LLC in Rhode Island uses Vensys turbine models.

The number of mid-size and large-scale turbine manufacturers and suppliers with installations in the United States has generally declined since 2012. For turbines greater than 100 kW, 10 different models for 18 distributed wind projects were supplied by five manufacturers and suppliers[7] in 2018. In 2017, nine different turbine models for 17 distributed wind projects were supplied by seven manufacturers and suppliers. In 2012, 27 manufacturers supplied 33 different mid-size and large-scale turbine models for 69 U.S. distributed wind projects.

A substantial amount of capacity using large-scale turbines has been installed to serve utility needs for local distribution grids. In past reports, utilities were considered part of the institutional customer type (see Section 8.1); however, as more utilities build or purchase power from distributed wind projects, separating these data is informative. For U.S. distributed wind projects using 1 MW-or-larger turbines, utilities accounted for 32% of capacity installed in 2015, 60% in 2016, 83% in 2017, and 50% in 2018.

Other than utilities, the bulk of 2018 projects using turbines greater than 1 MW were for industrial and government applications. For example, Valfilm, a plastic fabrication company located in Ohio, is a new customer for One Energy, which installed two 1.5-MW Goldwind turbines for the company in 2018. One Energy also

[7] In relation to manufacturers, suppliers refer to remanufacturers of domestic and imported turbines.

completed the installation of three additional 1.5-MW Goldwind turbines in 2018 for Whirlpool Corporation. Whirlpool now has a total wind capacity of 13.5 MW at its manufacturing facilities in Ohio. Regarding government customers, one 1.5-MW Vensys wind turbine was installed to power multiple municipal facilities for the town of Otis, Massachusetts. In addition to the 1.85-MW turbine at a Los Angeles County prison installed in 2017, Foundation Windpower installed one 1.7-MW turbine each to two additional California Department of Corrections and Rehabilitation facilities in 2018. Both One Energy and Foundation Windpower develop, own, and operate the distributed wind and sell the energy to their clients through power purchase agreements.

## 3.2 Small Wind

In 2018, 1.5 MW of small wind was deployed in the United States, representing 2,661 units and $8.2 million in investment. Impacted by changing federal and state policy environments and continued competition from low-cost solar photovoltaic (PV) technology, this continues the downward trend for small wind capacity of recent years. A total of 1.7 MW of small wind sales were recorded in 2017 (3,269 units and $11.5 million in investment), 2.4 MW in 2016 (2,560 units and over $14 million in investment), and 4.3 MW in 2015 (1,695 units and a $21 million investment).

Since 2012, the number of small wind turbine manufacturers both operating and participating in the U.S. market has decreased. The eight small wind turbine manufacturers with a 2018 U.S. sales presence accounted for in this report consist of five domestic manufacturers headquartered in five states (Arizona, Colorado, Minnesota, Oklahoma, and Vermont) and three importers. In comparison, 31 small wind turbine manufacturers reported U.S. sales in 2012.

Of the seven foreign manufacturers who replied to PNNL's data request for this report, three reported sales in the United States in 2018—Eocycle (Canada), Hi-VAWT Technology Corporation (Taiwan), and XANT (Belgium). In 2017, four foreign manufacturers reported sales in the United States (Britwind Limited, C&F Green Energy, Eocycle, and Hi-VAWT Technology Corporation), three reported sales in 2016 (Hi-VAWT Technology Corporation, Kingspan Environmental Limited, and Potencia Industrial), and two different foreign manufacturers reported 2015 sales in the United States (Gaia-Wind and Sonkyo Energy). This suggests that no single foreign small wind manufacturer has a strong, consistent presence in the U.S. distributed wind market.

U.S. small wind manufacturers accounted for 76% of the 2018 U.S. domestic small wind sales capacity. While the number of foreign small wind manufacturers that reported sales in the United States in 2018 was low at three, the larger size of the small wind imported turbines (25 kW and greater) reduced the U.S. small wind manufacturers' domestic market share. U.S.-based small wind manufacturers still account for most U.S. small wind sales, but the 76% market share represents a substantial decline from 94% in 2017, 98% in 2016, and the nearly 100% reported in 2015. Given the inconsistent presence of foreign manufacturers in the U.S. small wind market, this market share division may shift again.

Based on 2018 global sales in terms of capacity (megawatts of domestic sales and exports), the top three U.S. small wind turbine manufacturers were Primus Wind Power of Colorado, Northern Power Systems (NPS) of Vermont, and Bergey WindPower of Oklahoma.

Figure 6 shows annual domestic, export, refurbished, and import sales of small wind turbines. No sales of refurbished small wind turbine units have been reported since 2014.[8]

Since 2012, the number of small wind turbine manufacturers both operating and participating in the U.S. market has decreased. In 2012, 31 manufacturers reported U.S. sales; however, only eight manufacturers reported sales in the United States in 2018. In 2016, at least five small wind turbine manufacturers (Xzeres Corporation, Endurance Wind Power, Black Island Wind Turbines, Wind Turbines Industries Corporation, and UGE International), went out of business or changed hands. For the businesses that changed hands, the new owners did not report to PNNL sales of the acquired turbine models in 2018. In 2017, at least one manufacturer, Pika Energy, ceased sales of its wind turbine products and now is solely focused on solar PV and

[8] Most refurbished wind turbines sold in 2012 were installed in Nevada and received Section 1603 funding and NVEnergy incentive program funding.

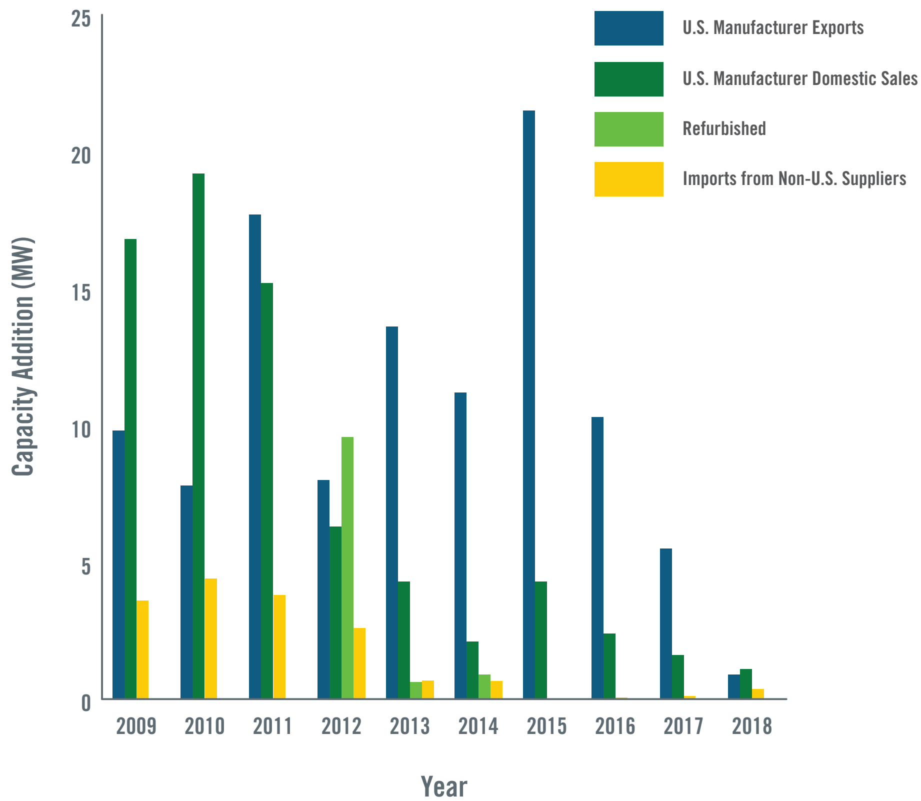


**Figure 6.** U.S. small wind turbine sales and exports, 2009–2018

energy storage. In 2018, Dakota Turbines started pursuing a buyer for its small wind business. And in 2019, NPS completed sales of multiple business units (Globe Newswire 2019; McQuiston 2019). NPS sold its service business to Erie Renewables, Inc. and its energy storage business to WEG Electric Corporation. NPS has indicated that the company is exploring the option of selling all of its assets and business lines including its distributed wind turbine models.

Small wind turbine manufacturers based in the United States self-report that they rely mostly on a domestic supply chain for most of their mechanical, electrical, tower, and blade components. However, some parts and materials, namely generator magnets, are imported either directly by the manufacturer or by a supply chain vendor. Multiple domestic small wind manufacturers reported that their costs were impacted in 2018 by the import tariffs on materials sourced from China implemented by U.S. Trade Representative Section 301 Investigations (USTR 2019).

While the U.S. small wind market is slow, some installers report they are busy with solar PV and turbine repair work, both domestically and internationally, along with repowering small wind projects. With some turbine manufacturers unable to support existing installations because they are no longer in business, and some of the older installed small wind turbines reaching the top end of their lifecycle, repowering opportunities (i.e., replacing a turbine on an existing tower) could be a source of growth for the small wind installer community.

## 3.3 Small Wind Exports

U.S. small wind turbine manufacturers also export to international markets. Since 2012 (the first year of the Distributed Wind Market Report), at least 71 MW of U.S. small wind turbines have been exported to at least 26 different countries at an estimated value of $428 million.

From a peak in 2015, these exports have been declining. Three U.S.-based small wind manufacturers exported turbines totaling just under 1 MW in capacity with an estimated value of $4.6 million in 2018. This is down significantly from 5.5 MW valued at $42 million from four manufacturers in 2017, 10.3 MW valued at $62 million from six manufacturers in 2016, and a peak of 21.5 MW of small wind exports from six manufacturers valued at $122 million in 2015.

The primary markets for U.S. small wind exports over the years have been the United Kingdom, Italy, and Japan because of those countries' feed-in tariff (FIT) programs.[9] In the peak year for exports, 2015, 99% of U.S. small wind turbine manufacturers' exports went to these three countries. However, all of these programs have changed and may continue to change, thus impacting the attractiveness of the market for U.S. small wind manufacturers. In 2018, U.S. small turbine manufacturers still reported exports to the United Kingdom and Japan, although at lower capacity levels than past years. A total of 47% of reported U.S. small wind exports went to the United Kingdom and Japan, and no exports to Italy were reported in 2018.

Figure 7 illustrates export market fluctuation in Italy, the United Kingdom, and Japan. The 60-kW turbine model from NPS has been the dominant export to Italy in past years, driving the higher export capacity values in Italy compared to the United Kingdom and Japan where smaller capacity units from U.S. manufacturers were deployed. In Japan, which remains a strong small wind market, a drop in exports can be attributed to a drop in sales by Xzeres Wind Corporation. Xzeres is a U.S. small wind turbine manufacturer that has historically exported mainly to the Japanese market. The following sections provide more details on exports in these three countries.

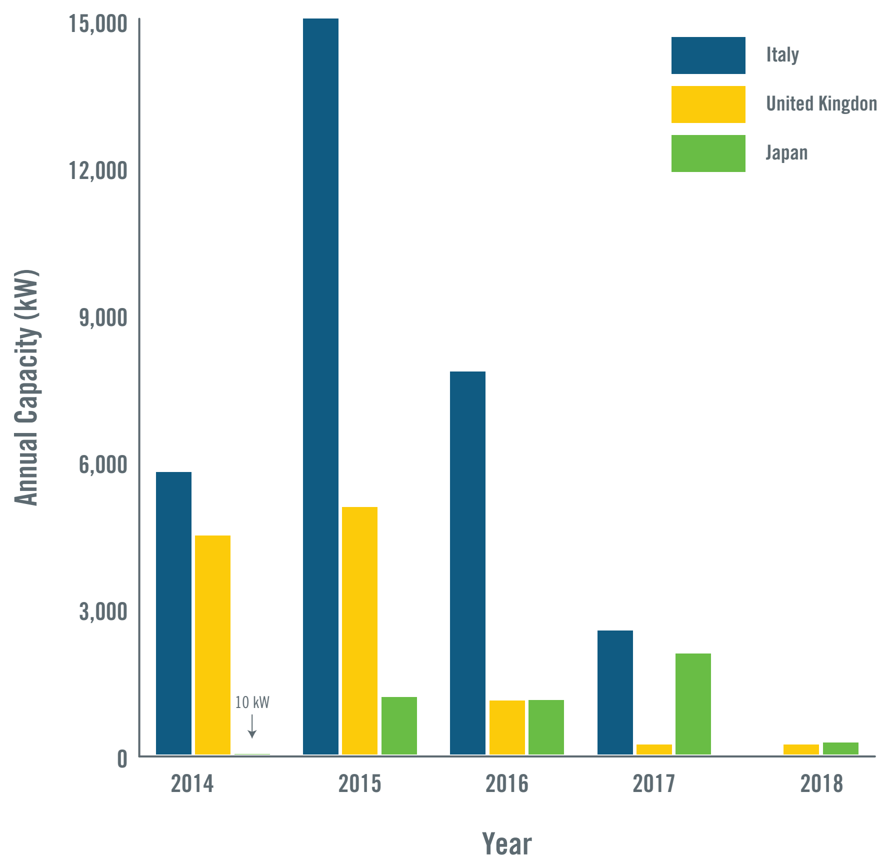


**Figure 7.** Key small wind export markets for U.S. manufacturers, 2014–2018

[9] A feed-in tariff is a long-term, fixed-price contract for renewable-generated electricity.

### 3.3.1 Italy

Italy's small wind market has experienced some swings over the past several years driven by the country's inconsistent FIT program. Italy had 16.3 MW of new small wind capacity (defined in Italy as turbines sized 250 kW or less) installed in 2014, 9.8 MW in 2015, 57.9 MW in 2016, and 77.5 MW in 2017 (ASSIEME 2018). PNNL was unable to obtain a small wind installed capacity value for 2018. U.S. small wind manufacturer exports to Italy were 5.7 MW in 2014, 15 MW in 2015, 7.8 MW in 2016, 2.5 MW in 2017, and no reported exports in 2018.

In the 2015 to 2016 timeframe, the FIT rate ranged between 0.11 and 0.25 Euro (12¢ and 28¢),[10] per kilowatt-hour (kWh). At the same time, it was known that the FIT rate would decrease in June 2017 and expire in December of 2017 (GSE 2016). According to Italy's wind industry association, Associazione Italiana Energia Mini Eolica, the impending end of the FIT accelerated the timeline of many projects so they could receive the funding while it was still available.

A new FIT program was expected to be launched in March 2019, but the launch has not occurred as of June 2019. The new FIT rate is expected to be lower, and the program is expected to have shared budget caps with solar PV projects, which increases competition for funding. Italy has been the primary export market for Vermont-based NPS for the past few years. Discontinuation of the FIT, along with other issues, has strained NPS operationally, commercially, and financially (Globe Newswire 2019). Without a reinstatement of the FIT program, NPS and other U.S. small wind manufacturers are unlikely to pursue the Italian market in the future.

### 3.3.2 United Kingdom

The small wind market in the United Kingdom has been declining steadily as the country's FIT program has also been reduced and restricted. Exports from U.S. small wind turbine manufacturers have declined in step with changes in the FIT. U.S. small wind manufacturer exports to the United Kingdom were 5 MW in 2015, 1.1 MW in 2016, 200 kW in 2017, and 200 kW in 2018. Overall installations in the country also follow this decline. In 2014, a peak of 28.5 MW of small wind was installed in the United Kingdom. Installations dropped to 11.7 MW in 2015, 7.7 MW in 2016, 393 kW in 2017, and 420 kW in 2018 (DBEIS 2019).

The FIT program has been through many iterations. In late 2015 and early 2016, the FIT underwent the first of several sweeping changes. In October 2015, the government announced significant changes to the FIT regime, including a deployment cap, as well as a decrease in the incentive value for turbines sized up through 100 kW from 13.73 pence (18¢) to 8.61 pence (11¢) per kWh, and the complete removal of incentives for turbines sized 1.5 MW and greater (DECC 2015a). After announcing the tariff changes, the government received nearly 55,000 public comments in response to the decision (DECC 2015b). As a result of the comments, the government reconsidered the program. After a total suspension of the program between January 15 and February 7, 2016 (DECC 2015b, OFGEM 2019), the FIT was reinstated in May 2016. In addition, the Department of Energy and Climate Change introduced a quarterly deployment cap of 5.6 MW for turbines sized up to 50 kW and 0.3 MW for turbines sized 50 to 100 kW (DECC 2015b).

In late 2017, the government announced that subsidies for renewable energy, including the FIT, would be canceled after April 2019 (Vaughan 2017), and no new applications to the FIT were accepted after March 31, 2019 (DBEIS 2018). The FIT rates for the last period of program, January to March 2019, were 8.24 pence (11¢) for turbines up to 50 kW, and 4.87 pence (6¢) for turbines 50 to 100 kW (OFGEM 2019).

[10] All currency conversions are based on the exchange rates per U.S. Department of the Treasury Reporting Rates of Exchange as of March 31, 2019, found at https://www.fiscal.treasury.gov/reports-statements/treasury-reporting-rates-exchange/current.html for reference.

### 3.3.3 Japan

In the wake of the 2011 Fukushima Daiichi nuclear disaster, Japan established many new renewable energy goals and programs, including a FIT available to small wind. U.S.-based small wind turbine manufacturers reported 1.1 MW of small wind sales to Japan in both 2015 and 2016, 2 MW in 2017, and 240 kW in 2018.

Japan has been the primary export market for Oregon-based Xzeres for the past few years. Xzeres established a Japanese subsidiary in 2013; however, because of a drop in sales, the subsidiary filed for bankruptcy in April 2019 in Tokyo (Teikoku Databank 2019). Like NPS focused on the Italian market, Xzeres focused on Japan; its drop in sales in Japan are the primary reason for the drop in exports to Japan in 2018.

This drop in sales is likely a result of an undisclosed incident reported in 2018 to the Japan Ministry of Economy, Trade and Industry that resulted in ClassNK (Japan's certification body) to temporarily suspend the Xzeres turbine model from its list of certified turbines eligible for the FIT. The suspension was removed in early 2019, but another incident in February 2019 resulted in the Xzeres turbine model being temporarily suspended again in April 2019, further prompting Xzeres' bankruptcy filing (METI 2019).

In 2018, Japan reduced the FIT rates for wind. For 2018, the rate for small wind turbines less than 20 kW dropped from 55 Yen (50¢) per kWh to 20 Yen (18¢) and dropped again to 19 Yen (17¢) for 2019. For turbines 20 kW and greater, the FIT rate dropped from 21–22 Yen (19–20¢) per kWh to 20 Yen (18¢) in 2018, and to 19 Yen (17¢) in 2019 (ITA 2018).

While the FIT rates are lower now than in previous years, the rates still are considered the highest available in the global market, and U.S. and international manufacturers are expected to continue pursuing this market (Shibata and Hanada 2019). Non-U.S. small wind manufacturers, notably Ghrepower (China), also see Japan as a high-priority market. Ghrepower has a reported 4.8 MW of its turbines in Japan (Shibata and Hanada 2019).

In 2015, even with the generous FIT at its peak rates (55 Yen [50¢] and 22 Yen [20¢]), interconnection restrictions by utilities and the country-specific certification requirements for grid-connected turbines hampered initial growth. Japan installed just 364 kW of small wind in 2015, 952 kW in 2016, and 2.85 MW in 2017 (HikaruWindLab 2016; METI 2015; Matsumiya 2018). But a total of 12.9 MW of small wind from 726 projects were installed in 2018, and there are close to 8,000 projects totaling 153 MW in the FIT approval queue (Matsumiya and Kubo 2019).

## 3.4 Global Small Wind Market

The U.S. small wind market and exports from U.S. small wind manufacturers contribute to the overall global small wind market. For 2018, PNNL documented 47 MW of new small wind capacity in seven countries. This is 59% lower than the 114 MW of international small wind PNNL documented for 2017. It also is lower than the 122 MW documented for 2016. This large decrease in reported deployment from 2017 to 2018 may be attributed partly to data availability. In 2017, deployment in Italy accounted for approximately 70% of global installations, but 2018 data for Italy were not available. Regardless, as that market has stalled, there may be few to no installations to report. Japan and Denmark both saw significant increases in deployment from 2017 to 2018, each with an increase greater than 300%.

Total global installed cumulative small wind capacity is estimated to be at least 1.7 GW as of 2018 as shown in Table 1. Small wind is generally defined as turbines up through 100 kW, but deviations from this definition are noted in the table footnotes.

## Table 1. U.S. small wind and the global market

| | 2013 (MW) Installations | 2014 (MW) Installations | 2015 (MW) Installations | 2016 (MW) Installations | 2017 (MW) Installations | 2018 (MW) Installations | Cumulative (MW) Installations | Cumulative Year Range |
|---|---|---|---|---|---|---|---|---|
| Australia[a] | * | 0.02 | 0.03 | * | 0.02 | * | 1.46 | 2001–2018 |
| Brazil[b] | 0.03 | 0.02 | 0.11 | 0.04 | 0.11 | 0.09 | 0.40 | 2013–2018 |
| Canada[c] | * | * | * | * | * | * | 13.47 | As of 2018 |
| Chinad[e] | 72.25 | 69.68 | 48.60 | 45.00 | 27.70 | 30.76 | 563.57 | 2007–2018 |
| Denmark[f] | 1.65 | 1.28 | 5.84 | 4.45 | 0.10 | 0.40 | 610.66 | 1977–2018 |
| Germany[g] | 0.02 | 0.24 | 0.44 | 2.25 | 2.25 | 1.00 | 30.75 | As of 2018 |
| Italy[h] | 7.00 | 16.27 | 9.81 | 57.90 | 77.46 | * | 189.43 | As of 2017 |
| Japan[i] | * | * | 0.36 | 0.95 | 2.85 | 12.88 | 21.31 | As of 2018 |
| New Zealand[j] | * | * | * | * | * | * | 0.19 | Through 2015 |
| South Korea[k] | 0.01 | 0.06 | 0.09 | 0.79 | 0.08 | 0.06 | 4.08 | As of 2018 |
| United Kingdom[l] | 14.71 | 28.53 | 11.64 | 7.73 | 0.39 | 0.42 | 141.40 | As of 2018 |
| United States | 5.60 | 3.70 | 4.30 | 2.43 | 1.74 | 1.50 | 150 | 2003–2018 |
| Global | 101.27 | 119.82 | 81.22 | 121.54 | 112.69 | 47.11 | 1,726.71 | |

*Data not available

[a] www.cleanenergyregulator.gov.au

[b] www.aneel.gov.br

[c] The Atlas of Canada - Clean Energy Resources and Projects (CERP)

[d] China Wind Energy Equipment Association

[e] Chinese Wind Energy Association

[f] www.energinet.dk; 0-100 kW capacity

[l] www.gov.uk, Monthly MCS and ROOFIT degression statistics

[g] Bundesnetzagentur; Bundesverband Kleinwindkraftanlagen; 0-50 kW capacity

[h] www.assieme.ed; 0-250 kW capacity

[i] Japan Small Wind Turbines Association (JSWTA)

[j] Sustainable Electricity Association of New Zealand

[k] Korea Energy Association

[l] www.gov.uk, Monthly MCS and ROOFIT degression statistic

# 4 Policies, Incentives, and Market Insights

The U.S. distributed wind market is impacted by a number of factors, including availability of and changes in federal and state policies and incentives.

## 4.1 Policies and Incentives

Federal, state, and utility incentives and policies (e.g., rebates, tax credits, grants, net metering, production-based incentives, and loans) continue to play an important role in the development of distributed energy resources including wind.

Figure 8 shows the number and value of U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) grants and state incentives[11] given in each state for distributed wind projects in 2018. The combined value of all awards equals $8.9 million in six states.[12] This is lower than recent years ($13.3 million in nine states in 2017, $12.8 million in nine states in 2016, and $10.6 million in 10 states in 2015), and significantly lower than the peak of $100 million in 22 states in 2012.

While the number of USDA REAP wind grants has been low for a number of years, the drop in total incentive value can be attributed to a substantial drop in NYSERDA awards (i.e., 30 awards totaling over $2 million in 2017 and one award of $173,100 in 2018); a drop in Iowa production tax credit payments, as some projects have completed their 10-year eligibility period; and the lack of Section 1603 awards granted in 2018. Many projects are in the queue for NYSERDA's small wind turbine program incentive, but were not completely installed and interconnected by the end of 2018.

The absence of Section 1603 awards is notable as they constituted a significant portion of the incentive awards in past years. The federal ITC was temporarily augmented in 2009 to allow for cash payments from the federal government in lieu of the tax credit, otherwise known as the U.S. Treasury cash grants or Section 1603 payments. To qualify for Section 1603 payments, wind power projects must have applied for a grant before October 1, 2012 and be placed in service by 2011, or began construction in 2009, 2010, or 2011 and placed in service by December 31, 2016. Because payments were made after the project was placed in service, not prior to or during construction, payments continued through 2017. A total of 201 distributed wind projects were granted $63 million in payments in 2012. This fell to 36 projects and $7.6 million in 2013, 11 projects and $650,000 in 2014, 17 projects and $990,000 in 2015, two projects and $143,000 in 2016, and two projects and $286,000 in 2017. No new payments were reported by the U.S. Treasury in 2018 (Treasury 2018).

[11] State incentives include rebates, production-based incentives, and production tax credits. Figure 8 excludes repaid loans, the federal ITC, and federal depreciation. New Mexico and Iowa state production tax credit values are estimated based on available project energy production reports.

[12] Incentive funding and commissioning of distributed wind projects are often not coincident. For example, although USDA REAP grants are recorded for this report in the year they are awarded, they are paid after the project is commissioned.

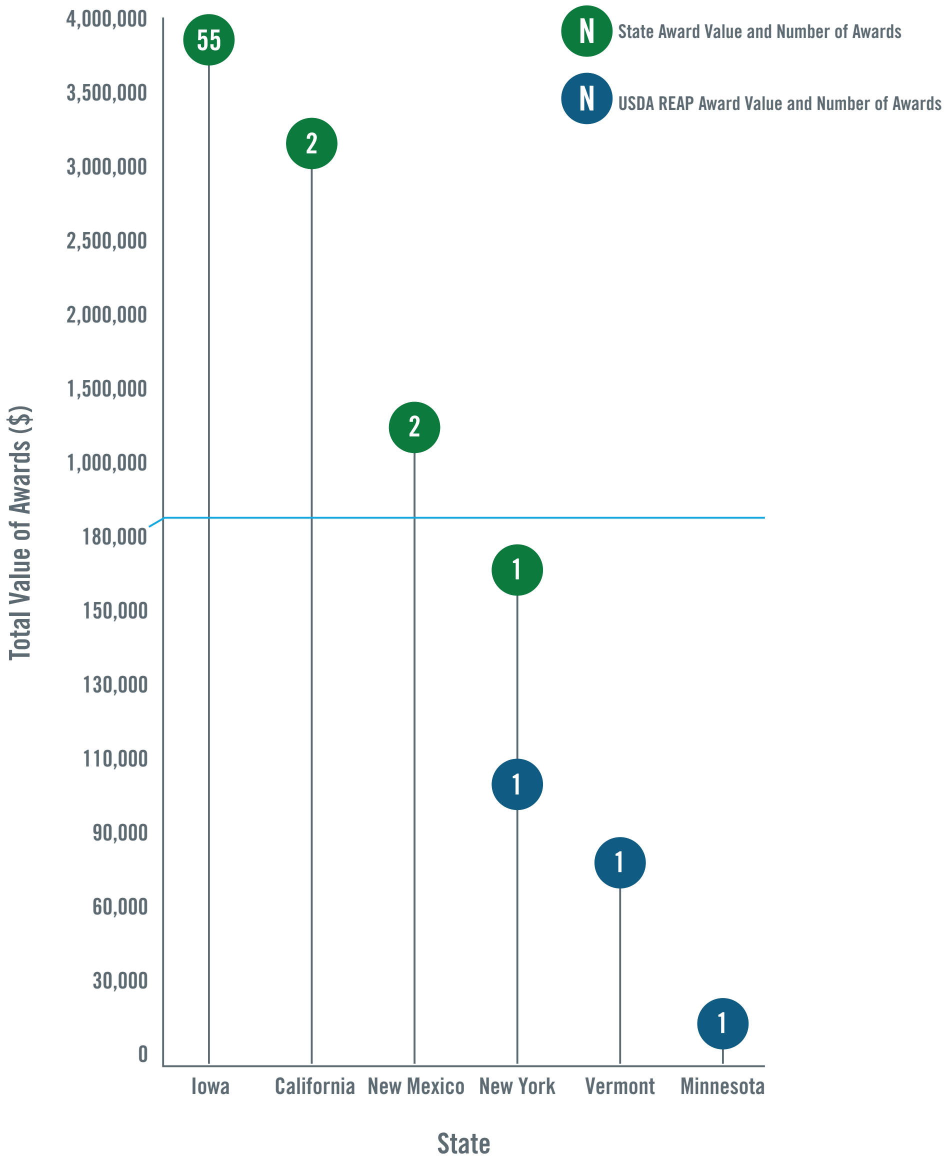


**Figure 8.** 2018 U.S. distributed wind incentive awards

### 4.1.1 State Policy and Incentive Highlights

State renewable portfolio standard requirements, net metering policies, interconnection standards and guidelines, FITs, utility programs, and the availability of grants, rebates, performance incentives, and state tax credits can impact the cost effectiveness and deployment of distributed wind in a state.

State incentive programs, such as rebates and production-based incentives, vary widely, and fewer states are providing these incentives. In 2012, 12 state programs reported incentive payments for distributed wind projects. Since then, at least New Jersey, Oregon, Vermont, Wisconsin, and Wyoming have discontinued their incentive programs or have excluded wind from eligibility. In 2018, four state programs reported incentive payments for distributed wind projects as shown in Figure 8. In 2017, the same four states plus Oregon reported incentive payments.

Although some state incentive programs still exist, there are few programs specifically for distributed wind. Incentive programs that are available to multiple types of distributed energy resources often receive few distributed wind applications. This low application rate is also experienced in the USDA REAP grant process (see Section 4.1.3) and was discussed in more detail in the *2015 Distributed Wind Market Report*.

There are a couple of likely reasons state programs receive fewer distributed wind applications. When equal incentives are provided, on a per kilowatt basis, the incentive will cover much more of the initial solar PV capital cost than an equivalent incentive for wind because wind has higher initial per-kilowatt capital costs (see Figure 10). The consumer may decide that the out-of-pocket expense of a small wind project is too high and the system will not be cost-effective, and therefore, no application is submitted. Another possible explanation may be the wind resource in the program's service territory is not sufficient to drive interest in and enable cost-effective wind energy projects (Orrell et al. 2016).

### 4.1.2 Federal Tax-Based Incentives

The overall wind industry has been affected by federal policy uncertainty. Wind deployment cycles have been demonstrably influenced by extensions and periodic expirations of federal tax incentives (DOE 2015). Changes to federal tax incentives also have impacted small wind deployment, as shown in Figure 9.

Figure 9 overlays introductions and changes in important federal policies, including the ITC and the Section 1603 cash grants, with domestic sales and imports from non-U.S. manufacturers of small wind turbines between 2007 and 2018. It also overlays the year (2010) when residential solar PV installed costs started to drop below small wind installed costs. Residential solar PV costs continue to be lower than small wind costs, giving solar PV a competitive advantage (also see Figure 10).[13]

Figure 9 illustrates that many small wind projects are not yet cost effective without federal policy support. The introduction of incentive funding and the ending of programs have a direct impact on the amount of small wind sales in the United States. For example, the inclusion of small wind in ITC funding in 2008 was followed by four years of strong domestic sales. Conversely, small wind sales have declined since the Section 1603 cash grant application deadline in late 2012. In addition, the phasing out of important federal incentive programs also led to decreased interest from non-U.S. manufacturers.

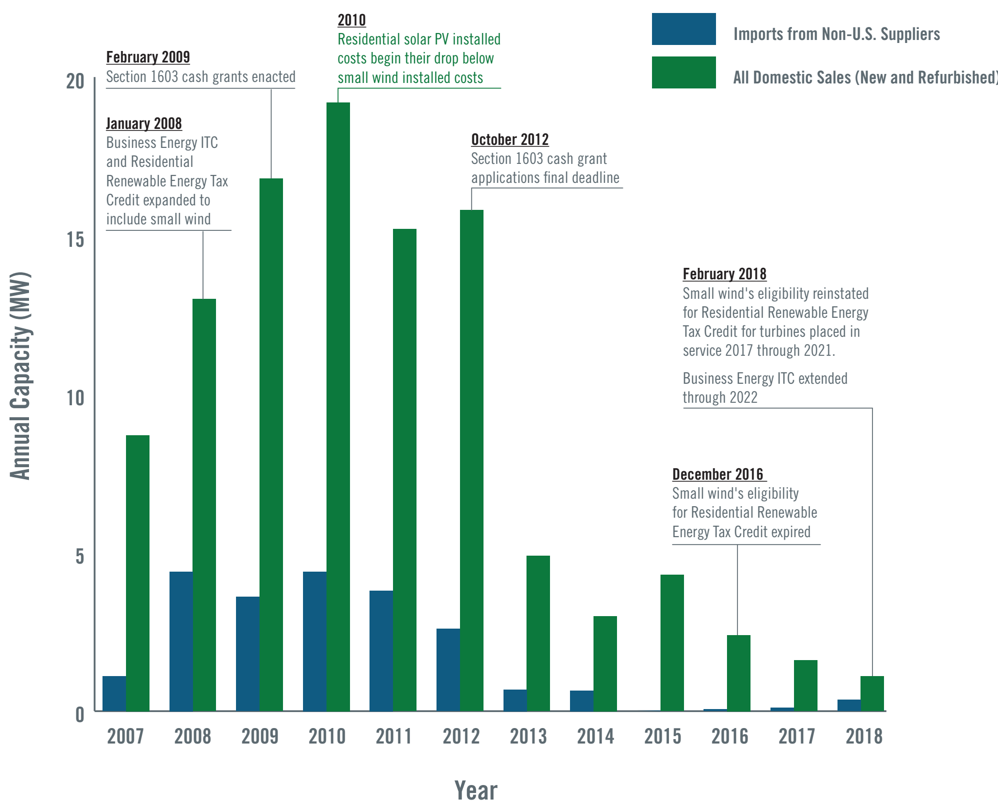


**Figure 9.** U.S. small wind sales and federal policies, 2007–2018

[13] Residential is a customer segmentation used in the *Tracking the Sun* report (Barbose and Darghouth 2018) for single- and multiple-family housing solar PV installations. Residential solar PV is comparable to small wind because agricultural and residential customers who choose to install wind predominantly use small wind turbines.

The federal Business Energy Investment Tax Credit (26 U.S.C. § 48) and the Residential Renewable Energy Tax Credit (26 U.S.C. § 25D) both provide tax credits for a portion of the capital costs of eligible renewable energy projects. Small wind's eligibility for the Residential Renewable Energy Tax Credit expired in 2016, but was reinstated for 2017 through 2021. The Business Energy Investment Tax Credit also was extended through 2022.[14]

PNNL estimates that 520 kW of the small wind projects documented in 2018 were eligible for the 30% federal tax credit (i.e., estimated capacity excludes non-taxable entities), representing a value of approximately $850,000 based on average small wind installed project costs.

### 4.1.3 U.S. Department of Agriculture Rural Energy for America Program

USDA provides agricultural producers and rural small businesses grant funding as well as loan guarantees to purchase or install renewable energy systems or make energy-efficiency improvements. Through REAP, USDA issues loan guarantees for renewable energy projects for up to 75% of the project's eligible cost or a maximum of $25 million. USDA also issues REAP grants for up to 25% of the project's cost, or a maximum of $500,000 for renewable energy projects. A project can have both a REAP loan and grant, in which case these awards could cover a maximum of 75% of total eligible project costs.

In 2018, USDA REAP funded three wind projects (180 kW, four turbines) with $209,335 in grants from four applications that are expected to generate a combined 495,000 kWh of energy annually. REAP also provided one loan guarantee in 2018 for a 1.7-MW single turbine project. While the funding amount for 2018 was larger than the $43,586 in grants awarded in 2017 (52.2 kW, five turbines), the number of projects funded (three) and total applications (four) is the same for both years. The total grant amount for 2018 is less than 2016 levels, when USDA provided $308,134 in grants for seven wind projects (400 kW, 8 turbines) and a significant decrease from 2012 through 2015, as shown in Table 2.

**Table 2. USDA REAP wind awards, 2012–2018**

| | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| Grant Awards | 57 | 25 | 15 | 24 | 7 | 3 | 3 |
| Grant Funding ($) | 2,554,043 | 1,193,984 | 405,442 | 1,395,748 | 308,134 | 43,586 | 209,335 |
| Loan Guarantees ($) | 15,357,837 | 4,207,205 | 1,295,818 | 5,207,360 | 0 | 0 | 1,986,794 |

Wind projects represented 0.29% of all 2018 REAP grant awards (0.5% of total REAP funding); energy-efficiency projects represented 28% of grant awards (22% of funding); and solar PV projects represented 67% of awards (57% of funding). Other awards include biomass, geothermal, and hydroelectric projects. In 2017, wind projects represented 0.25% of all REAP grant awards (0.12% of total REAP funding).

Since 2003, USDA has awarded nearly $72 million in REAP wind grants. States receiving the largest share of this funding are Iowa with $23.3 million, Minnesota with $21.3 million, Illinois with $4.1 million, Ohio with $2.9 million, and Oregon with $2.8 million. The top five states in terms of number of wind projects awarded are Iowa with 264 projects, Minnesota with 172, New York with 49, Wisconsin with 45, and Alaska with 30.

## 4.2 Market Insights

Other factors beyond policy decisions and changing incentives, such as technology innovations and new market development, impact the distributed wind market. This section provides a few highlights of these type of activities.

[14] Small wind's eligibility for the Residential Renewable Energy Tax Credit expired December 31, 2016. The Bipartisan Budget Act of 2018 (Public Law 115-123 as of February 2, 2018) reinstated eligibility for the tax credit for small wind turbines placed in service in 2017 through 2021. The Act also extended the Business Energy Investment Tax Credit for small wind projects that start construction by the end of 2022. Both have phase-down schedules. For small wind, the Business Energy Investment Tax Credit phase-down schedule is 30% of qualified expenditures for systems that start construction through the end of 2019, 26% in 2020, and 22% in 2021and 2022. For the Residential Renewable Energy Tax Credit, the schedule is 30% for systems placed in service through the end of 2019, 26% in 2020, and 22% in 2021.

### 4.2.1 Rural Development

Many of the regions in the United States that offer quality wind resources, high retail rates, and population densities acceptable for distributed wind development are rural. One distributed wind industry player is entering this rural market through agreements with agricultural providers. United Wind, a wind leasing company, has partnered with both Clif Bar to bring distributed wind to its network of organic farmers in Iowa, Minnesota, North Dakota, and South Dakota, and with Smithfield Foods, Inc. to power dozens of hog farms in Colorado (United Wind 2019; NACE 2019).

Distributed energy resources, such as wind, contribute energy generation to microgrids, hybrid energy systems, and distribution networks. For example, in 2018, Juhl Energy Development Inc. brought a solar PV-wind hybrid project online in northwest Minnesota that includes a 1.7-MW GE wind turbine and 500 kW of solar PV combined through GE's Wind Integrated Solar Energy technology platform. The energy produced will be distributed over local Lake Region Electric Cooperative power lines and will help provide rate stability for the entire cooperative membership. Juhl Energy has proposed the installation of two additional hybrid systems in Wisconsin.

### 4.2.2 Competitiveness Improvement Project

The DOE Competitiveness Improvement Project (CIP) awards cost-shared contracts via a competitive process to manufacturers of small and medium[15] wind turbines. The goals of the project are to reduce hardware costs, make wind energy cost competitive with other distributed energy resources, and increase the number of wind turbine designs certified to national testing standards. CIP grants fund efforts across three research areas: 1) system optimization, 2) advanced manufacturing, and 3) turbine certification testing. Through six funding cycles, DOE has awarded 28 subcontracts to 15 companies, totaling a $6.3 million DOE investment across the three research areas while leveraging an additional $3.5 million in private sector funding. The first commercial installation of the new Bergey Excel 15 turbine, a CIP system optimization awardee, was completed in February 2019.

### 4.2.3 Turbine Certification

Certifying a turbine model to a standard is the industry approach to demonstrate that the turbine model meets performance and quality standards. Certifications issued by independent, accredited certification bodies allow wind turbine sellers to demonstrate compliance with regulatory and incentive program requirements. Certified ratings also allow purchasers to directly compare products and help funding agencies and utilities gain greater confidence that small and medium turbines installed with public assistance have been tested for safety, function, performance, and durability and comply with standards.

As of January 2015, small wind turbines must meet either the AWEA Small Wind Turbine Performance and Safety Standard 9.1-2009[16] or the IEC 61400-1, 61400-12, and 61400-11 standards to be eligible to receive the Business Energy Investment Tax Credit (IRS 2015).[17]

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[15] International and domestic certification standards define wind turbines based on their rotor swept area, rather than their nameplate capacity. For certification purposes, small wind turbines are those having rotor swept areas up to 200 $m^2$ (approximately 50 to 65 kW in nameplate capacity), and medium wind turbines are those having rotor swept areas greater than 200 $m^2$.

[16] A new standard, American National Standards Institute (ANSI)/AWEA SWT-1, was approved in 2016, and the industry is in the transition phase of adopting this standard for widespread use. The AWEA Small Wind Turbine Performance and Safety Standard 9.1–2009 is still applicable and referenced in IRS guidance, but may be replaced by ANSI/AWEA SWT-1 in the future.

[17] This certification requirement does not apply to wind projects that first qualify to take the production tax credit but then opt out to instead receive the Business Energy Investment Tax Credit (26 U.S.C. § 48), nor is it codified in the Residential Renewable Energy Tax Credit (26 U.S.C. § 25D) requirements.

Table 3 lists the ten small wind[18] turbine models certified to the AWEA standard or the IEC standards as of report publication. Three new turbine models, the Hi-VAWT Technology Corporation DS3000, the Bergey WindPower Excel 15[19] and the Primus AIR 30/AIR X, were certified in 2019. The Hi-VAWT DS3000 is the first vertical-axis wind turbine to demonstrate conformance to the AWEA standard and be certified by the International Code Council-Small Wind Certification Council (ICC-SWCC).

**Table 3. Certified small wind turbines[20]**

| Applicant | Turbine | Date of Initial Certification | Certified Power Rating[a] @ 11 m/s (kW) | Certification Standard |
|---|---|---|---|---|
| Bergey WindPower | Excel 10[b] | 11/16/2011 | 8.9 | AWEA |
| Bergey WindPower | Excel 15[b] | 6/4/2019 | 15.6 | AWEA |
| Dakota Turbines | DT-25[b] | 7/18/2018 | 23.9 | AWEA |
| Eocycle Technologies, Inc. | EO20/EO25[c] | 9/21/2017 | 22.5/28.9 | AWEA |
| Hi-VAWT Technology Corporation/Colite Technologies | DS3000[b] | 5/10/2019 | 1.4 | AWEA |
| Lely Aircon B.V. | LA30[b] | 1/13/2017 | 27.2 | AWEA |
| Primus Wind Power | AIR 40/Air Breeze[d] | 2/20/2018 | 0.16 | IEC |
| Primus Wind Power | AIR 30/AIR X[d] | 1/25/19 | 0.16 | IEC |
| SD Wind Energy, Ltd. | SD6[b] | 6/17/19 (renewed)[21] | 5.2 | AWEA |
| Xzeres Wind Corporation | Skystream 3.7[b] | 12/19/2011 | 2.1 | AWEA |

[a] Power output at 11 m/s (24.6 mph) at standard sea-level conditions. Manufacturers may describe or name their wind turbine models using a nominal power, which may reference output at a different wind speed (e.g. 10 kW Bergey Excel 10). [b] Certified by ICC-SWCC [c] Certified by SGS [d] Certified by DEWI-OCC, UL

The certification process is a significant upfront and ongoing investment. This is one reason the number of certified turbine models fluctuates. The ICC-SWCC, an accredited certification body, requires an annual renewal of certification with a paid fee, and a manufacturer may opt not to renew if it no longer wants to sell that turbine model because of unfavorable distributed wind market conditions or because of a change in the company's business focus. As of June 2019, the number of certified turbine models was down to ten—from 16 in May 2018—because many manufacturers did not renew their certifications.

High cost is one reason certification testing is supported by DOE through CIP. The majority of small wind turbine manufacturers are small businesses and the certification investment can represent a large percentage of their overall annual expenses. Small and medium wind turbine manufacturers in the United States have reported that certification costs, including fees, direct expenses, and labor time, range from $150,000 to $500,000. In the latest CIP request for proposals (issued March 2019), applicants were eligible for certification testing awards of up to $170,000 and 20% cost share for turbines with rotor swept areas up to 200 m$^2$, and up to $800,000 and 20% cost share for turbines with rotor swept areas greater than 200 m$^2$.

While certifying a turbine model to a standard allows a turbine manufacturer to demonstrate that a turbine model meets performance and quality standards, the international distributed wind community has identified some limitations in the current standards applicable to small and medium wind turbines. Standards are reactive; their requirements are based on past experience and knowledge and may not reflect evolving wind technology and its widening range of potential applications. In response, the International Energy Agency (IEA) approved the creation of a new task—Task 41: Enabling Wind to Contribute to a Distributed Energy Future—in March 2019. One of the objectives of the new task is for international stakeholders to collaborate to make potential standards changes recommendations. Other aspects of the task include development of a distributed wind data sharing portal, research on the integration of wind with other distributed energy resources on microgrids, and outreach and collaboration across IEA and other international agencies addressing distributed wind and other distributed energy resources issues.

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[18] At least four medium wind turbine models—Ghrepower FD21-50, NPS 100-21, Vergnet GEV MP, and XANT M-21—have published power performance and acoustics certifications to IEC 61400-12-1 (power) and IEC 61400-11 (acoustics).

[19] As of report publication, the Excel 15 has completed the power performance test and ICC-SWCC has certified the results, but the turbine model must complete the duration test before ICC-SWCC can grant full certification.

[20] Rated sound levels and rated annual energy production values also are available for these certified turbines (ICC-SWCC 2019; CESA 2013).

[21] The SD Energy SD6 turbine model certification is a renewal of the Kingspan Environmental KW6, but under a new model name because of new ownership. SD Energy Energy acquired Kingspan's wind turbine product line in 2018 (Business Wire 2018).

# 5 Installed and Operations and Maintenance Costs

Cost data presented in this section were derived from state and federal agencies, project owners and developers, installers, and news reports. Data categorization reflects the distributed wind cost taxonomy (Forsyth et al. 2017). The taxonomy, or classification system, allows for consistent names and categories to evaluate distributed wind turbine installation and operation and maintenance costs. It also provides a structure to establish benchmarks.

## 5.1 Small Wind Installed Costs

Because of the extremely low number of small wind project records with installed cost data, a 2018 average cost analysis is not presented in this report. Instead, historical data are revisited and the average annual project-specific small wind installed costs for 2009 through 2017 are presented in Figure 10 along with residential solar PV installed costs for the same time period. All costs in Figure 10 are in 2017 dollars and before any incentives are applied. Small wind installed costs are per rated kilowatt capacity. Residential solar PV costs are from the *Tracking the Sun 2018 Edition* report (Barbose and Darghouth 2018).

As shown in Figure 10, small wind project-specific installed costs, as reported by installers and state and federal agencies, have increased since 2009 and have been fairly flat since 2014. This is in contrast to residential solar PV costs which have been steadily dropping over the years.

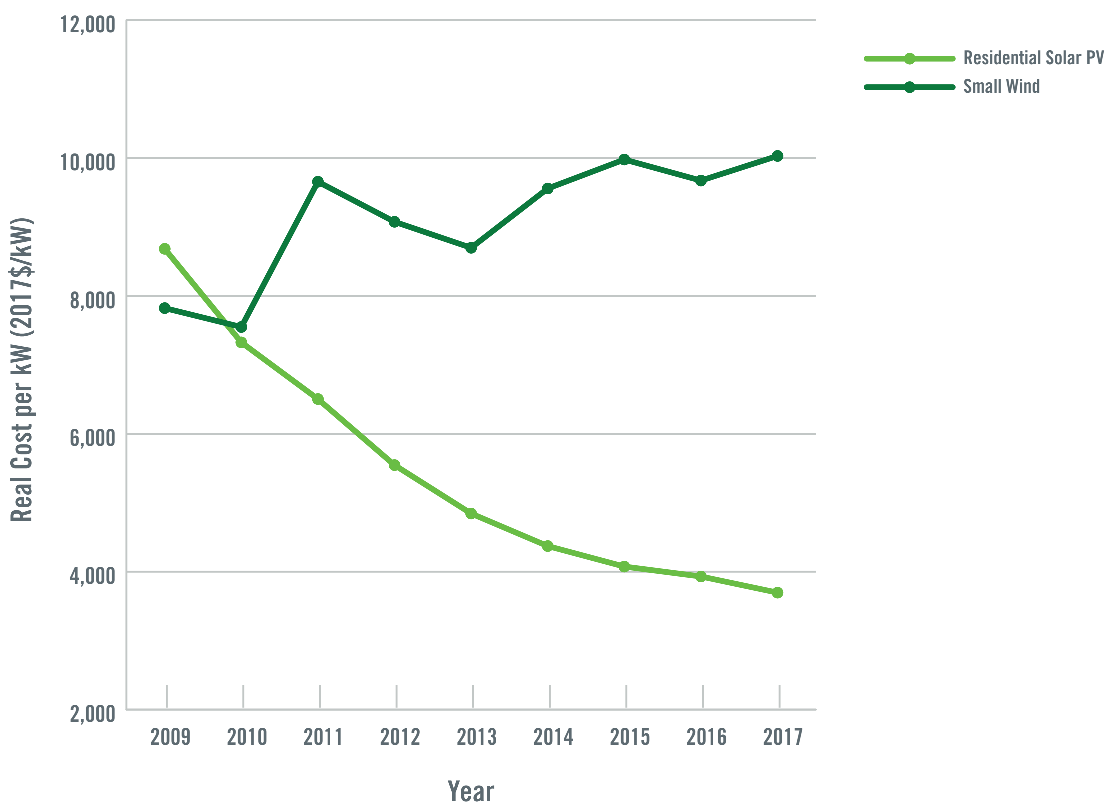


**Figure 10.** Small wind and residential solar PV installed costs, 2009–2017

Previous analysis that compared small wind installed costs to residential solar PV installed costs used manufacturers' reported average small wind costs. Figure 11 instead uses project-specific reported installed costs. The manufacturers provided typical installed cost estimates for turbine models in the past, primarily based on their turbine system equipment costs. The data suggest that actual installed costs are impacted greatly by non-turbine system equipment costs and site-specific issues, such as foundation and construction requirements, local installation labor, permitting requirements, and shipping costs. These balance of station costs can represent up to 60% of a small wind project's total installed cost and therefore play a significant role in overall small wind installed costs.[22]

## 5.2 Installed Costs for Projects Using Wind Turbines Greater than 100 kW

For projects using turbines greater than 100 kW installed in the United States in 2018, installed project cost information was available for 11 projects across four states using 12 turbines for a total of 28.9 MW. The average per kW cost of these projects is $4,437/kW. The average cost for 2017 projects (six projects,

40.1 MW) was $3,014/kW in 2018 dollars, and the average cost of 2016 projects (eight projects, 11.3 MW) was $4,106/kW in 2018 dollars. The average costs for projects using turbines greater than 100 kW for years 2009 through 2018 are presented in Figure 11.

The availability of cost information for distributed wind projects using turbines greater than 100 kW varies from year to year. As a result, the average costs reported each year likely contain bias because of the project sample size variation (i.e., military project costs may dominate one year's sample while cost information for projects located in Minnesota may dominate another year).

The decline in average cost from 2016 to 2017 and then the increase in 2018 is an example of this. In 2017, the drop in average cost was driven by a 30-MW project portfolio in Iowa that is actually six different sites, connected behind different substations to provide power to ethanol and biodiesel facilities on those local distribution grids. This 30-MW, multi-site project likely benefited from economies of scale and bulk turbine purchase pricing, which drove down its installed cost and the 2017 average installed cost. Conversely, the 21 MW of distributed wind capacity installed in Rhode Island in 2018 was also by a single developer at multiple sites, but its much higher total project cost dominated the 2018 sample size. There may be many reasons for the Rhode Island projects' higher cost, including state-based differences such as permitting and labor availability.

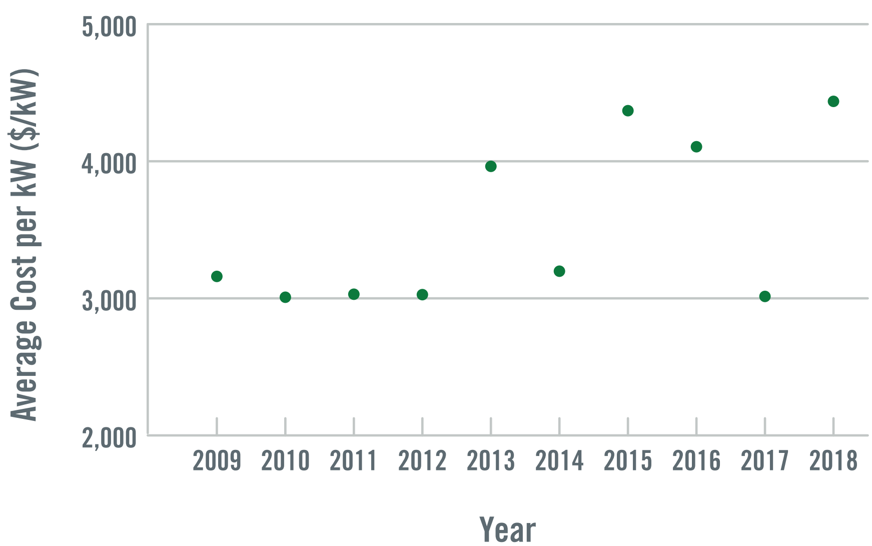


**Figure 11.** Average installed costs for projects using turbines greater than 100 kW, 2009–2018

[22] Soft costs and balance-of-station costs are explored in detail in *Benchmarking U.S. Small Wind Costs* (Orrell and Poehlman 2017).

## 5.3 Operation and Maintenance Costs

Operation and maintenance costs is a common term, but operation costs differ from maintenance costs, and not all distributed wind projects experience them equally. Operation costs for wind projects may include land lease payments, remote monitoring, various operations contracts, insurance, and property taxes. Operations are a significant expense for wind farms and large distributed wind projects; however, they typically are not substantial, or even present, for small distributed wind projects. On the other hand, all wind projects, distributed or otherwise, require maintenance.

For a large distributed wind project, operation and maintenance costs of the turbine system are part of the project's total operating expenses. The *2018 Wind Technologies Market Report* (Wiser and Bolinger 2019) reports that projects using turbines greater than 100 kW installed in 2018 have an expected operating expense of $43/kW/year.

For small wind systems, the project installer or developer performs the maintenance for the system owner in most cases. Maintenance costs include labor, travel to the site, consumables, and any other related costs. Therefore small wind maintenance costs can depend on the maintenance provider's proximity to the project site (i.e., travel costs), the availability of spare parts, and the complexity of maintenance and repairs.

Maintenance costs can be categorized as scheduled or unscheduled. Scheduled maintenance activities can include inspecting the turbine, controller, and/or tower; adjusting blades; checking production meter and communications components; and providing an overall annual scheduled maintenance visit per the manufacturer's owner's manual. Unscheduled maintenance activities can include a wide variety of activities, ranging from responding to a customer's complaint of noise from the turbine to replacing the generator, electrical components, inverter, blades, or anemometer.

Scheduled maintenance site visit costs for a sample of small wind projects were collected for the *Benchmarking U.S. Small Wind Costs* report (Orrell and Poehlman 2017). Scheduled maintenance is typically performed annually. Costs reflected labor, travel, consumables, parts, and other miscellaneous costs. That data showed the average scheduled maintenance cost per visit is about $37/kW.

This is in line with other data that suggest operation and maintenance costs for all distributed wind systems up to 10 MW are consistent at $30 to $40 per kW per year (NREL 2016). As a result, the levelized cost of energy (LCOE) calculations in this report (see Section 7.0) use a $40/kW/year value for O&M costs as the largest project in the dataset is 6.9 MW.

# 6 Performance

A wind project's capacity factor is one way to measure the project's performance. The capacity factor is a project's actual annual energy production divided by its annual potential energy production if it were possible for the wind turbine to operate continuously at its full capacity.[23]

The capacity factors of distributed wind projects from three datasets—USDA REAP, NYSERDA, and EIA—were calculated based on the annual energy generation values reported in the datasets. The capacity factors are the average of three consecutive yearly capacity factors. To be included in the capacity factor analysis, projects needed to have three consecutive years of reported performance data and a known rated, or reference, capacity.

For the NYSERDA dataset, the analysis considers 12 consecutive months of operation as a year, rather than a calendar year. For the USDA REAP and EIA datasets, the analysis assumes the generation value for each year reported represents a full year of operation. Some project outliers were excluded based on unreasonably high capacity factors or year-to-year inconsistencies, assumed to be a result of data-entry errors. The NYSERDA, USDA REAP, and EIA datasets are used for this analysis, and provide input to PNNL's project dataset described in Section 1.3 and Appendix B.

## 6.1 Capacity Factors

Figure 12 presents the calculated small wind capacity factors, based on the average of the first three years of reported generation for each project, from the combined NYSERDA and USDA REAP datasets, and rated turbine capacity. Figure 13 presents the three-year average capacity factors for the projects using turbines greater than 100 kW, based on their EIA-reported annual generation values in 2015, 2016, and 2017 (the most current, consecutive year data available from EIA) and the total project capacity based on turbine nominal capacity.

The three-year average capacity factor for large-scale wind turbines in distributed applications is 31%. The three-year average capacity factor for projects using mid-size turbines is 25%. The three-year average capacity factor for small wind is 17%.

The sample sizes used in this report are slightly different than those in the *2017 Distributed Wind Market Report* in which the three-year average capacity factors were reported to be 32%, 20%, and 16% for large-scale, mid-size, and small wind, respectively.

The USDA REAP dataset includes 21 small wind projects (totaling 529 kW in rated capacity) in six states and 12 large-scale wind projects (totaling 20.2 MW) in two states that were awarded grants during the period from 2009 through 2014. After a grant is awarded, the recipient has up to two years to install the project. USDA REAP then requests, but does not require, that award recipients report actual annual generation amounts for three years after installation.

The NYSERDA dataset includes 72 small wind projects (totaling 1.34 MW in rated capacity) and one mid-size turbine project (275 kW) installed in New York during the period from 2010 through 2015 with reported production from 2010 through 2018. After installation, rebate recipients are required to submit performance reports at least twice a year for two years. Because of these NYSERDA and USDA REAP reporting arrangements, the analysis reflects those projects' first three years of operation.

The wide range of small wind capacity factors, from 2% to 36%, reflects, among other variables, the assessment and siting challenges for small wind described in the next section. The capacity factors for the 8.9-kW rated capacity turbines only range from 5% to 29%. The same turbine model sited in different locations can achieve very different capacity factors. In addition, low turbine availability, resulting from a turbine not operating for extended periods because of mechanical problems, can lower the turbine's overall annual capacity factor. Poor measuring and reporting of energy production may also be a factor.

[23] The small wind turbine capacity factor calculations use the turbines' rated, or reference, capacities, as defined in Appendix B, to be consistent with Section 5. For distributed wind projects using turbines greater than 100 kW, the turbine nominal capacities are used.

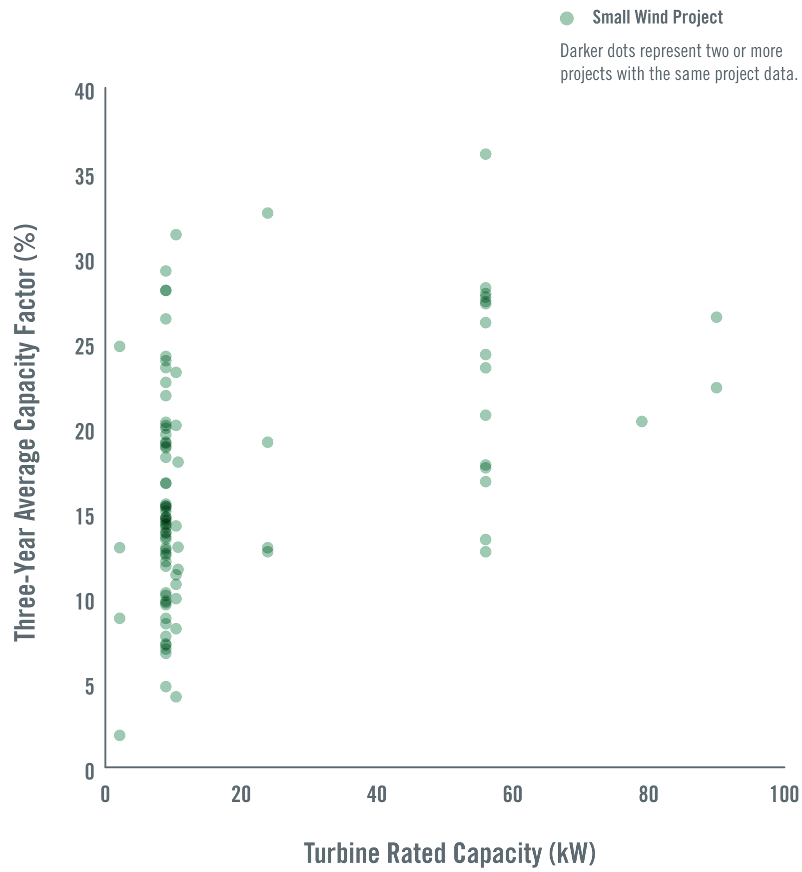


**Figure 12.** Small wind capacity factors

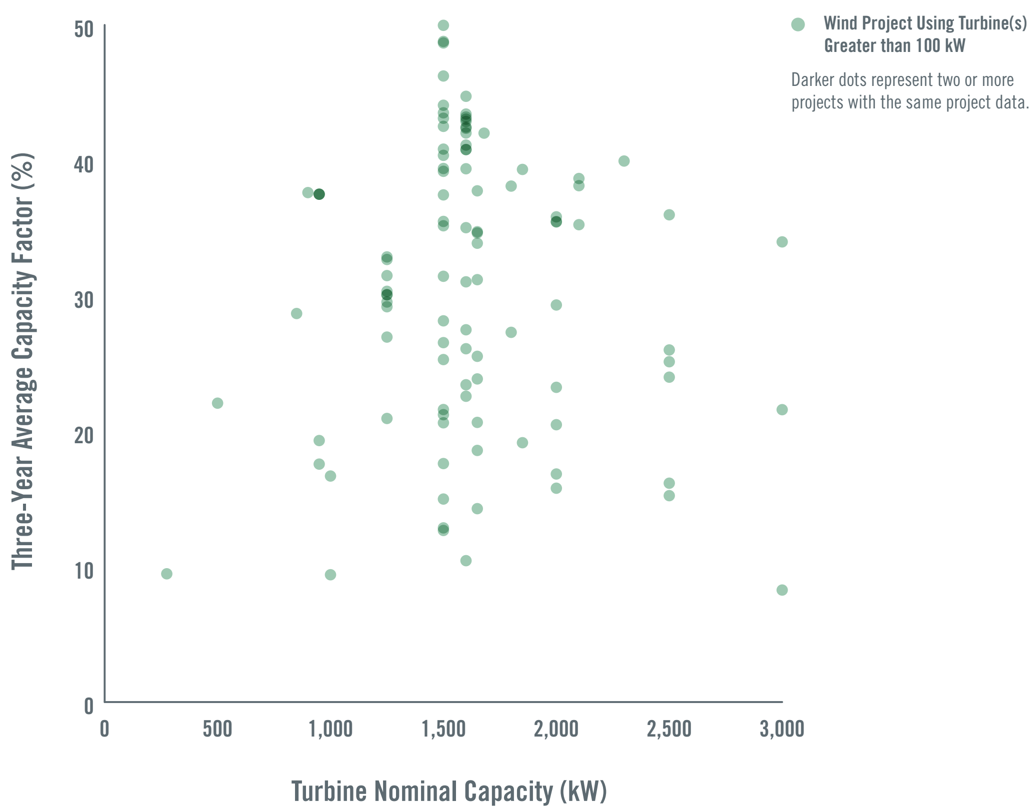


**Figure 13.** Capacity factors for projects using turbines greater than 100 kW

Wind projects with a total size of at least 1 MW are required to report net annual energy generation to the EIA in EIA-923 and EIA-860 reports (EIA 2019a). From these records, 89 distributed wind projects installed from 2003 to 2014, across 20 states, totaling 387 MW in capacity were analyzed.[24]

The average capacity factor in 2017 for all U.S. wind projects using turbines greater than 100 kW built from 2004 to 2011 was 31.5% (Wiser and Bolinger 2018), comparable to this report dataset's average of 31% and installation time frame of 2003 to 2014. However, the projects shown in Figure 13 also exhibit a wide range of capacity factors, ranging from 8% to 50%. While the analysis presents a three-year average capacity factor based on generation values for 2015, 2016, and 2017, these projects were installed from 2003 to 2014. This snapshot in time could account for some of the variation, but siting and turbine availability issues also may play roles in large-scale distributed wind project performance. Nonetheless, the large-scale turbine project three-year average capacity factor is higher than that of small wind because large-scale turbine projects are more likely to have had a thorough wind resource assessment as part of the siting process to achieve optimal energy generation, and undergo routine maintenance to maintain high levels of reliability.

## 6.2 Actual versus Projected Project Performance

Actual performance can vary relative to projected performance. The inability to consistently and accurately predict performance can negatively impact consumer confidence in distributed wind, as well as access to financing.

This analysis compares the projects' predicted annual generation values against the projects' three-year average annual generation values based on three consecutive years of operation to account for inter-annual variability. PNNL calculated each project's three-year average generation value and compared that to the project's projected generation value to establish what percent of projected production each project achieved. Figure 14 presents these comparisons for different turbine size categories—small certified turbines, small non-certified turbines, and large-scale turbines. Mid-size turbines are excluded from Figure 14 because there was only one project with three years of performance data and a projected production value available. That project achieved 84% of its projected performance.

As shown in Figure 14, the full range of projected production values achieved ranges from as low as 1% to as high as 261%. For the distributed wind projects with very high over-performance values, the calculated capacity factors are physically possible, meaning the generation prediction was severely underestimated, or perhaps the wind resource in those years was significantly better than originally estimated.

Distributed wind projects using large-scale turbines generally achieved higher generation values than predicted, while small wind turbines generally achieved lower generation values than predicted. The certified small wind turbines exhibit a higher average of percent of projected production (90%) than the non-certified small wind turbines (58%). This difference is likely a result of many factors, as described below, and cannot be attributed solely to the turbine technology.

The Anderson Wind Project in New Mexico is an example of a large-scale project that has exceeded its estimated performance expectations. A project's estimated annual production value must be included in its application for the New Mexico Renewable Energy Production Tax Credit. The Anderson Wind Project is eligible to receive tax credit payments for a maximum of 52,560 MWh per its original application, but the EIA annual net generation for this project in 2017 was reported at 61,658 MWh.

The project-specific details that drive each project's actual energy generation amounts and the methodologies for predicting performance were not available for review for this report. The amount of annual energy production achievable by a distributed wind project is driven by variables beyond just turbine technology. These variables include the project's available wind resource, siting (e.g., tower height, local obstructions, and other micro-siting issues), and turbine availability (e.g., downtime for expected or unexpected maintenance).

[24] In the subsequent actual project performance and LCOE analyses, smaller subsets of these datasets are used because of outliers and missing information in some project records.

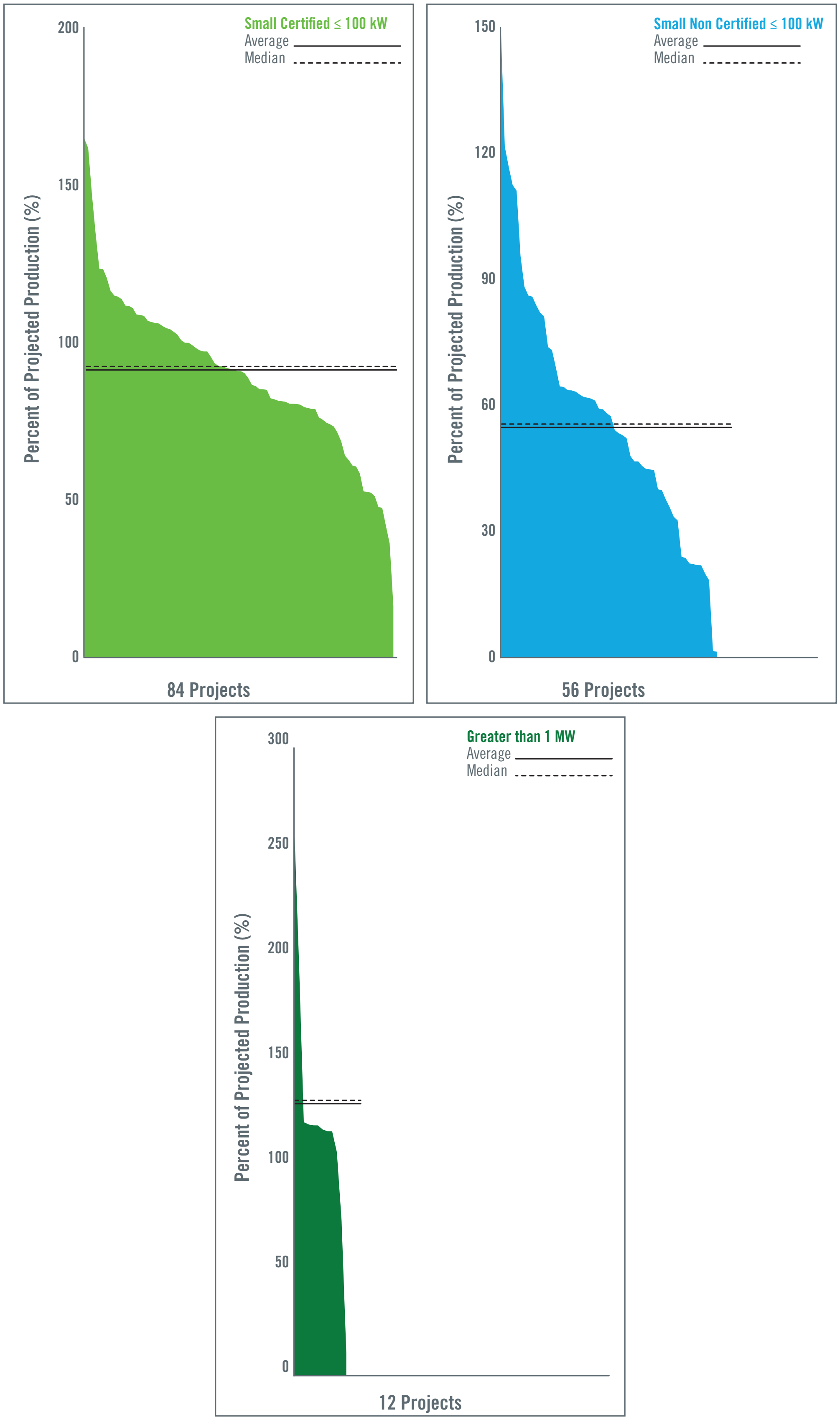


**Figure 14.** Actual performance for USDA REAP and NYSERDA projects

Some distributed wind systems may experience debugging issues in their first year of operation (e.g., fine-tuning the controller and fixing manufacturer defects), which means energy generation amounts in later years could be more representative of typical performance. There could be wind resource variability from year to year as well. The use of three-year average annual generation values based on three consecutive years of operation attempts to address this potential debugging issue and account for inter-annual wind resource variability. However, this small wind dataset still shows significant year-to-year energy generation variation.

From year one to year two for the small wind projects included in the actual performance analysis, approximately 56% of the projects increased in production and 44% decreased. From year two to year three, 51% of projects increased in production and 49% decreased. Overall, the evaluated dataset suggests that small certified turbines are likely to see a fluctuation in production from 4–15% from year to year, and small non-certified turbines are likely to see a fluctuation in production from 7–37%.

# 7 Levelized Cost of Energy

An LCOE represents the present value of all anticipated project costs (installed and O&M) over a project's anticipated lifetime of energy production. An LCOE, which allows different technologies of unequal life spans, sizes, and initial capital costs to be compared, is calculated by dividing a project's lifetime costs by its energy production and is expressed in terms of $/kWh or ¢/kWh. Appendix B describes the National Renewable Energy Laboratory's method and assumptions used to calculate distributed wind LCOE in this report (NREL 2013).

The representative annual energy production value used in each LCOE calculation is the project's three-year annual energy generation average calculated from the USDA REAP, NYSERDA, and EIA datasets. The LCOE calculations also use the projects' installed costs, incentive award values, and estimated annual O&M costs. All costs are in 2018 dollars. The LCOE analysis is limited to projects for which complete information is available.

## 7.1 Levelized Costs of Energy by Turbine Size Class

Figure 15 presents the calculated small wind LCOEs from the NYSERDA and USDA REAP datasets. Figure 16 presents the calculated LCOEs for the projects using turbines greater than 100 kW (which includes both mid-size and large-scale turbines) from the three combined datasets.

The small wind average LCOE after incentives was 23¢/kWh (from 86 projects totaling 2 MW in rated capacity). The mid-size turbine project average LCOE after incentives was 14¢/kWh (from three projects totaling 7.5 MW). The large-scale turbine project average LCOE after incentives was 5¢/kWh (from 27 projects totaling 120 MW).

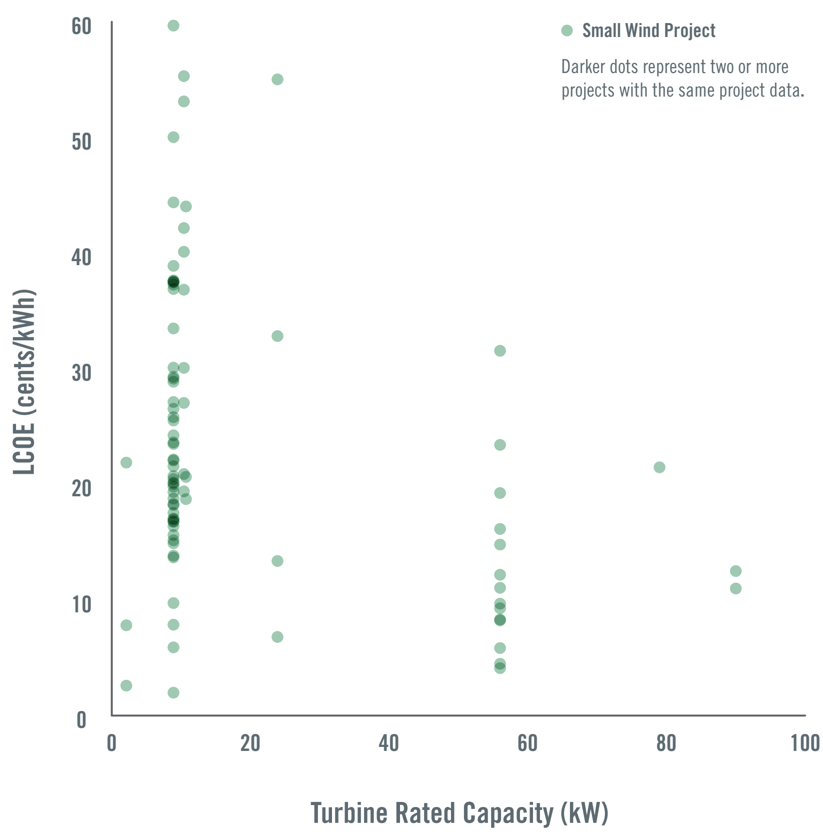


**Figure 15.** Levelized costs of energy (after incentives) for selected small wind projects

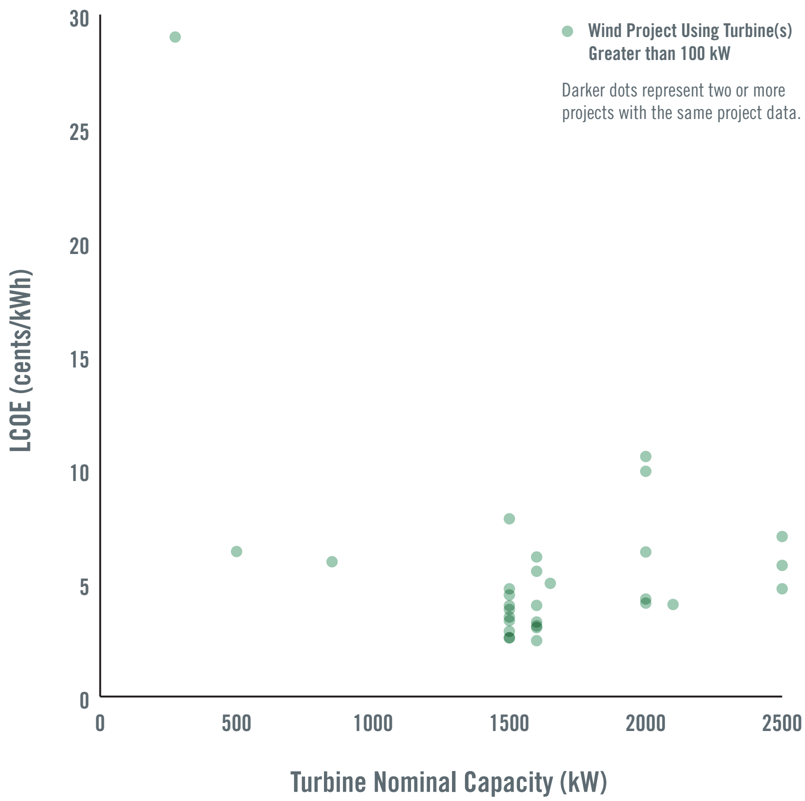


**Figure 16.** Levelized costs of energy (after incentives) for selected projects using turbines greater than 100 kW

If a project received a NYSERDA, REAP, and/or Section 1603 incentive, the installed capital cost used to calculate LCOE was reduced by the total incentive award amount.[25] Rebates and grants reduce the upfront cost for the wind turbine owner significantly and, thus, reduces the LCOE for the owner as well. Incentives reduced the small wind LCOEs in this sample by an average of 40% and LCOEs for the mid-size and large turbine projects by averages of 16% and 22%, respectively.

With these incentives, some of the distributed wind projects are cost competitive with retail electric rates. Behind-the-meter distributed wind projects displace some or all electricity purchased at retail rates. According to the EIA, average residential retail electric rates, which small wind turbines are most likely to displace, range from 9.3¢ to 23¢/kWh in the continental United States. Average commercial rates, which mid-size and large-scale turbines could displace, range from 7.7¢/kWh to 18¢/kWh (EIA 2019b). Hawaii, Alaska, Puerto Rico, the USVI, and Guam have higher rates, making distributed wind more cost competitive in those areas.

## 7.2 Levelized Costs of Energy and Capacity Factors

The relationship between calculated LCOEs after incentives and capacity factors is shown in Figure 17. In general, the higher the capacity factor, the lower the LCOE. Higher capacity factors, which in turn can reduce LCOEs, can be achieved by better siting, which can help increase energy production, and better turbine operations (i.e., higher turbine availabilities).

[25] NYSERDA rebates cover up to 50% of the project cost (via an incremental performance-based incentive). USDA REAP grants cover up to 25% of eligible project costs, or a maximum of $500,000. Section 1603 cash grants cover up to 30% of eligible project costs. For the small wind projects, one project had a combination of REAP, NYSERDA, and Section 1603 grants. One project had a REAP and a Section 1603 grant, and two projects had REAP and NYSERDA grants. The remaining projects had either only a REAP or only a NYSERDA grant. For the distributed wind projects that use turbines greater than 100 kW, one project received only a NYSERDA grant, one project received only a USDA REAP grant, one project received a USDA REAP grant and a Section 1603 grant, and the rest of the projects received only a Section 1603 grant.

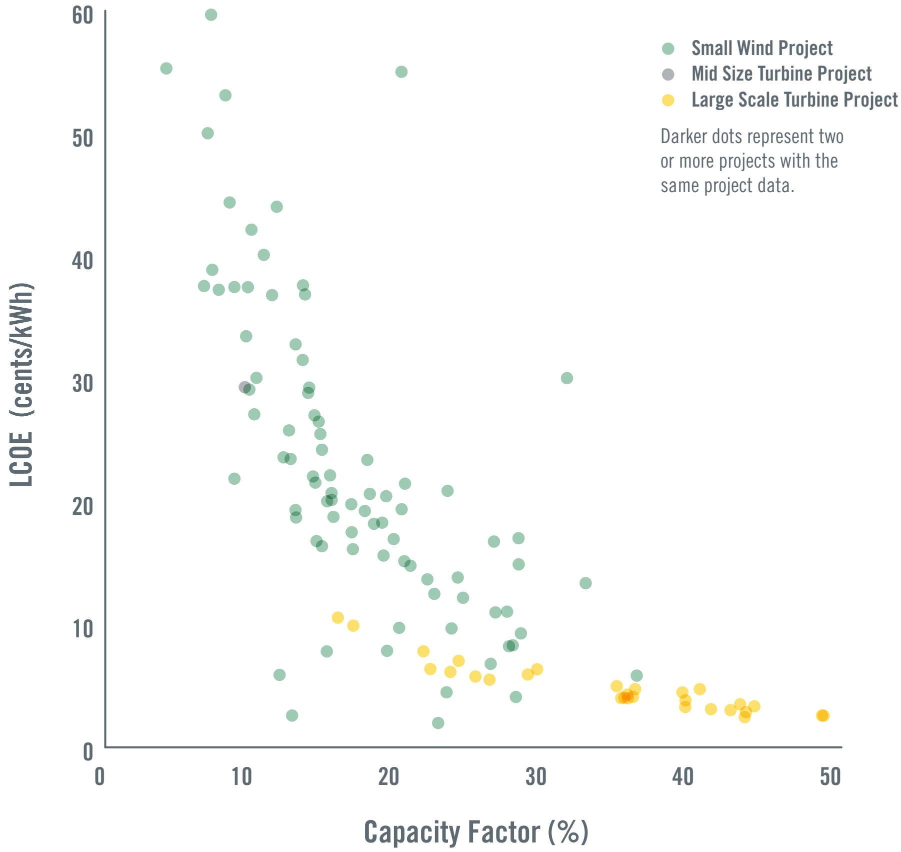


**Figure 17.** Levelized costs of energy (after incentives) and capacity factors

# 8 Distributed Wind Markets

This section of the report looks at some of the details, such as customer types and wind turbine types and sizes, for distributed wind sales and installations in 2018.

## 8.1 Customer Types

Customers install distributed wind systems for a variety of reasons—to increase energy security, lower utility bills, mitigate energy price volatility, or simply generate renewable energy. The distributed wind assets can either be owned directly by the customer or the customer could purchase energy from the distributed wind system. This report considers seven main customer types for distributed wind: 1) residential, 2) agricultural, 3) industrial, 4) commercial, 5) governmental, 6) institutional, and 7) utilities. In past reports, utilities were considered a type of institutional customer; however, as more utilities build or purchase power from distributed wind projects, separating utility from institutional customers is informative.

1. Residential applications include remote cabins, private boats, rural homesteads, suburban homes, and multi-family dwellings.
2. Agricultural applications include all types of farms, ranches, and farming operations.
3. Industrial applications are facilities that manufacture goods or perform engineering processes (e.g., food processing plants, appliance manufacturing plants, and oil and gas operations).
4. Commercial applications include offices, car dealerships, retail spaces, restaurants, and telecommunications sites.
5. Governmental applications are projects for non-taxed entities such as cities, municipal facilities (e.g., water treatment plants), military sites, and tribal governments.
6. Institutional applications are for entities that may also be non-taxed and mainly consist of schools, universities, and churches.
7. Utilities can be investor-owned or rural electric cooperatives.

Figure 18 shows the breakdown of customer types by number of projects[26] and by distributed wind capacity for 2018.

Residential and utility customers accounted for the same number of projects in 2018, but projects using large-scale turbines that serve utility customers account for the majority of distributed wind capacity. A total of 47% of capacity in 2018 was for utility customers compared to 78% in 2017.

In 2018, agricultural and residential customers accounted for a combined 1% of the documented capacity. These two customer types accounted for just under 3% of the documented capacity in 2017 and 7% in 2016. As agricultural and residential customers predominantly use small wind turbines, this decrease mirrors the decrease in small wind sales.

While the number of commercial and industrial projects have been fairly steady the past few years, the size of the turbines used in the projects have increased and thus the overall capacity of the projects has increased as well. Commercial and industrial projects represented almost 29% of the total project capacity documented in 2018, up from 9% in 2017 and 5% in 2016.

[26] The capacity and number of projects represented in this discussion are based on PNNL's project dataset. Small wind turbine sales with project-specific records were added to the project dataset, but most of the 2018 small wind units sold (i.e., off-grid turbine units) were not tracked at the project level.

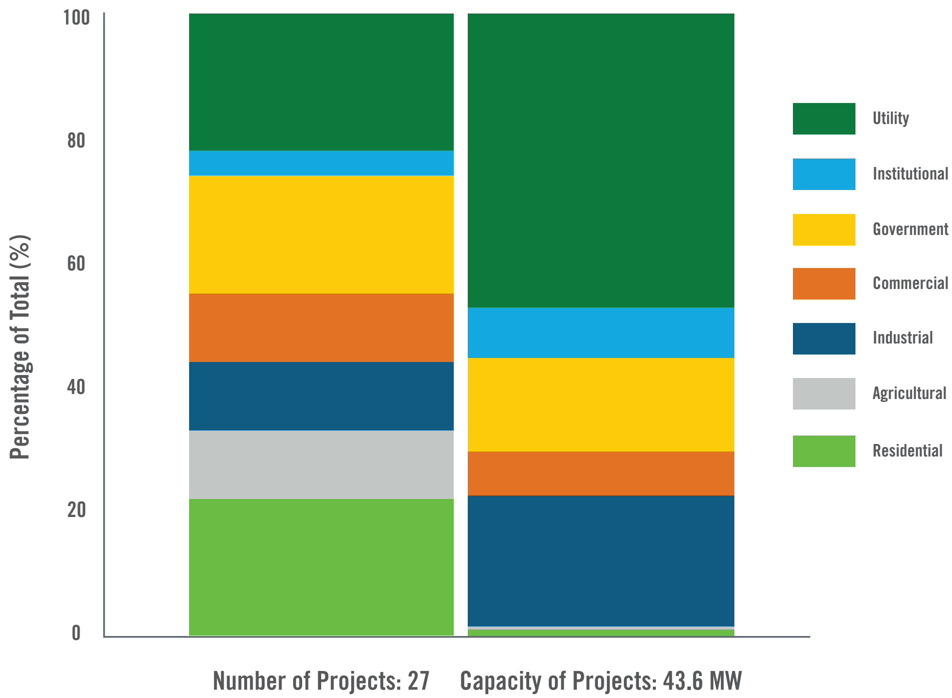


**Figure 18.** 2018 distributed wind customer types by number and capacity of projects

## 8.2 Onsite Use and Local Loads

Of the documented distributed wind capacity installed in 2018, 54% (nine projects) was connected to distribution grids serving local loads; specifically towns, a tribal community, public power district and rural electric cooperative service areas, and other utility service areas in Alaska, Massachusetts, Minnesota, Nebraska, and Rhode Island. The other 46% of capacity (19 projects), served onsite loads, either as behind-the-meter (98%), off-grid (1%), or remote net-meter (less than 1%) in Alaska, California, Indiana, Minnesota, New York, Ohio, Oklahoma, Rhode Island, Texas, and Vermont. In 2017, 80% of capacity was connected to distribution grids to serve local loads and 20% was for onsite loads; however, the breakouts for 2016 (40% for local loads, 60% for onsite loads) and 2015 (49% for local loads and 51% for onsite loads) are comparable to the 2018 breakout.

Wind systems that are connected directly to a local grid to support explicit local loads are considered distributed energy resources for this report. Distributed wind is differentiated from wholesale power that is generated at large wind farms and sent via transmission lines to substations for distribution to loads and distant end users. However, because of proximity to a city or other load center and the physics of electricity, some wind farms also may provide energy locally. In reviewing AWEA records for projects installed in 2018, PNNL determined that an additional 125 MW was not intended to provide distributed generation, but could because of the projects' locations.

## 8.3 Off-Grid and Grid-Tied

As discussed in more detail in Section 8.4, off-grid small wind turbine models continue to account for the bulk of wind turbine units deployed in U.S. distributed wind applications, but less than 1% of documented capacity. An estimated 88% of turbine units in 2018 distributed wind applications were deployed to charge batteries or power off-grid sites such as remote homes, oil and gas operations, telecommunications facilities, boats, rural water or electricity supply, or military sites. This is down from 2017 when 96% of turbine units were deployed in off-grid applications.

Grid-tied wind turbines accounted for nearly 100% of the annual distributed wind capacity (in megawatts) for projects that were tracked in both 2018 and 2017. This statistic reflects the fact that most of the small wind units sold, particularly the less than 1-kW size turbines used in off-grid applications, are not tracked at the project level.

## 8.4 Wind Turbine Sizes and Types

In 2018, reported U.S. distributed wind projects or sales encompassed 24 different turbine models[27] ranging in size from 150 W to 3.57 MW from 13 manufacturers and suppliers. This is comparable to 2017 (29 turbine models ranging in size from 150 W to 3 MW from 18 manufacturers and suppliers), 2016 (29 wind turbine models ranging from 160 W to 2.3 MW from 17 manufacturers and suppliers), and 2015 (24 different wind turbine models ranging from 160 W to 2.85 MW from 15 manufacturers and suppliers). In contrast, there were 34 different wind turbine models from 21 manufacturers and suppliers in 2014, 69 different models from 28 manufacturers and suppliers in 2013, and 74 different turbine models from 30 manufacturers and suppliers in 2012.

Because the wind market is not uniform, this report analyzes the market by turbine size or customer type, as needed. Different factors are at play for each turbine size segment, in part because some turbine sizes are more applicable for certain customer applications than others, so highlighting trends within those market segments is valuable.

Large-scale turbines in distributed applications dominate annual deployed capacity values and the trend toward higher capacity large-scale turbines is helping to drive the annual capacity values. As more customers use higher capacity large-scale turbines and fewer use mid-size turbines—which may be partially due to the limited number of commercially available mid-size turbines—the average nameplate capacity of turbines greater than 100 kW in distributed wind project continues to increase. An example illustrative of this trend is Green Development LLC's use of 3-MW Vensys wind turbines for its 2018 projects compared to their use of 1.5-MW turbines in its 2016 projects.

In 2003, the average turbine capacity used in distributed wind projects with turbines greater than 100 kW in size was 1.1 MW, as shown in Figure 19. In 2018, the average capacity size was 2.1 MW—almost double the capacity of turbines used in 2003. This trend mirrors the increase in turbine capacity size used for all land-based wind projects.

In comparison, small wind is bound by definition to be turbines 100 kW in size and less, so this market segment does not have the same turbine size growth potential as large-scale turbines. Instead, different factors (e.g., U.S. sales presence variation for manufacturers) impact the sizes of small wind turbines deployed from year to year.

As overall small wind capacity deployment has decreased annually, the less than 1-kW turbine size segment has contributed an increasingly large percentage of both the total deployed units and the total deployed capacity for small wind. In 2012 (the first year for reliable small wind unit and capacity values), turbines less than 1-kW in size accounted for 7% of the deployed small wind capacity and 70% of the units. In 2018, the less than 1-kW turbine size segment accounted for 47% of the deployed small wind capacity and 99% of the units.

[27] Turbine models can be new, refurbished, or retrofitted units. The definition of what constitutes a refurbished (or remanufactured or reconditioned) wind turbine varies. A refurbished turbine may be one that only had a few new parts added to the unit or simply had a change of hydraulic or transmission fluids before being resold. Alternatively, a refurbished turbine could have undergone an extensive remanufacturing process in which all of its parts were fully rebuilt. A retrofitted turbine is typically a new turbine (i.e., nacelle, rotor, and generator) installed on an existing tower. For federal ITC eligibility, a turbine must be new, where new is defined as having no more than 20% used parts. Therefore, some refurbished and retrofitted turbines do qualify for the federal ITC.

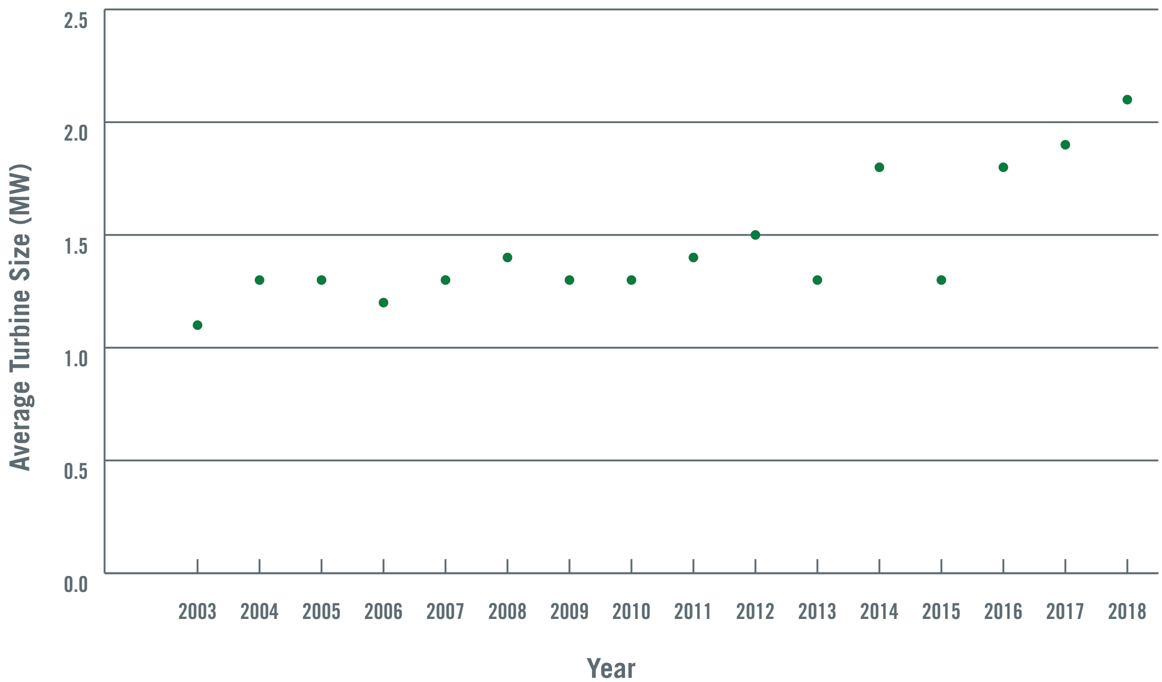


**Figure 19.** Average size of turbines greater than 100 kW in distributed wind projects, 2003–2018

A few factors likely contribute to this trend. The less than 1-kW turbines are used primarily in off-grid or battery charging applications, are often sold in a package integrated with solar PV, and demand for remote power is less sensitive to market conditions. While capacity deployment in all turbine size segments fluctuates from year to year, the variation is greater in the 1 to 10 kW and 11 to 100 kW size segments. This yearly variation, segmented by small wind turbine size, is shown in Figure 20.[28]

This variation is a result of inconsistent sales due to changing market conditions and turbine manufacturer business operations. The single-year presence of a given manufacturer can significantly impact overall small wind sales capacity (e.g., the 11- to 100-kW turbine category in 2015 compared to 2017). So while sales of turbines with capacity less than 1 kW have remained fairly level year to year, the less than 1-kW turbines now account for a larger share of the small wind market because there are fewer sales in the other size segments.

Approximately 133,000 wind turbines of all sizes have been deployed in the United States since 2003. While a significant number of these units are deployed in distributed applications, driven by the less than 1-kW size segment, distributed wind accounts for about 1% of all installed wind capacity in the United States.

This report captures sales from the manufacturers who responded to the report's annual data request. While PNNL has an extensive data collection process (see Appendix B for details on the report's methodology), it is likely that some manufacturers were missed, particularly small wind vertical-axis wind turbine (VAWT) manufacturers. In this report, VAWT models represent about 4% of U.S. small wind market units and 2% of capacity for 2018, where most of these units are in the less than 1-kW size segment. This percentage is slightly higher than recent past years in which VAWT representation has been about 1% to 2% of U.S. small wind capacity.

[28] The corresponding units for the annual deployed capacities are presented in the accompanying data file available at https://www.energy.gov/eere/wind/downloads/2018-distributed-wind-market-report.

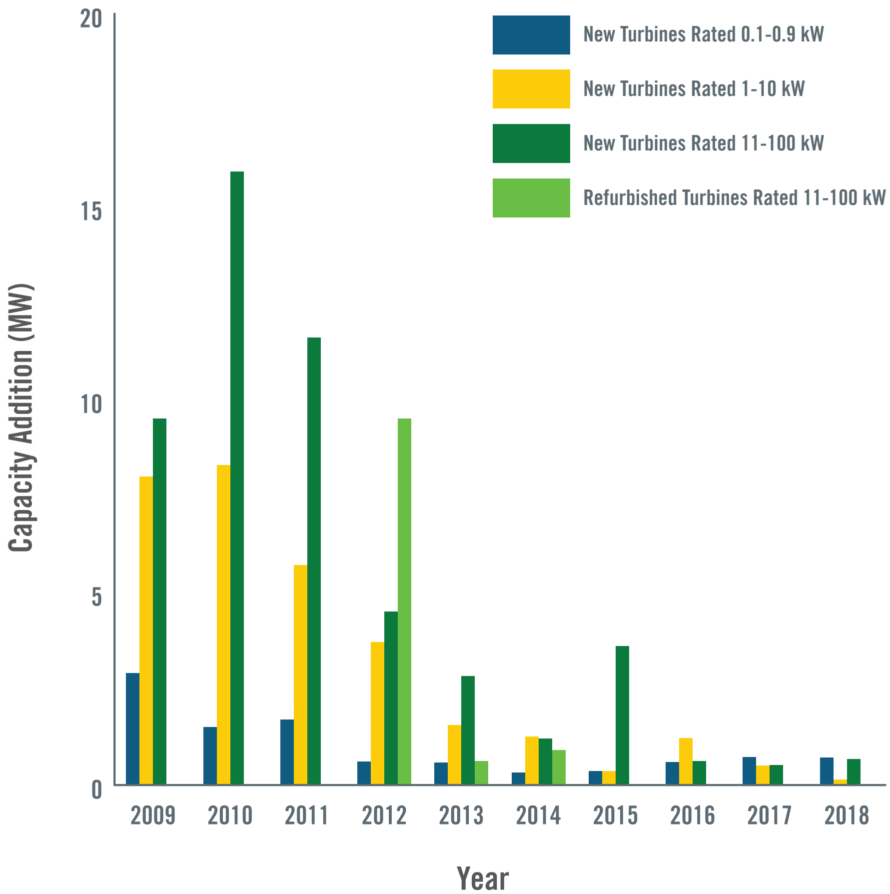


**Figure 20.** U.S. small wind sales capacity by turbine size

## 8.5 Type of Towers

Because of the low amount of small wind deployment, PNNL was unable to collect a significant sample of small wind project-level details. Of the 22 different projects for which PNNL was able to collect tower type information, primarily projects using turbines greater than 100 kW, 20 of the projects used self-supporting monopole towers. Reported hub heights range from 30 m for a 100 kW turbine to 130 m for the behind-the-meter 3.57 MW turbine at the UL Advanced Wind Turbine Test Facility, while other large-scale turbine hub heights ranged from 80 to 98 m.

# 9 Summary

This report documents trends and statistics for the U.S. distributed wind market, which varies year to year with respect to both customer types and deployment levels among and within the turbine size segments (i.e., small, mid-size, and large-scale). While this report's definition of distributed wind captures a wide range of wind technology applications—from a 400 W turbine on an oil and gas platform to a 3 MW turbine providing energy for a utility's distribution grid—market conditions, policies, and customer demands do not impact the different sectors of the distributed wind market uniformly.

The U.S. small wind market has been steadily declining since a peak in 2012. To reverse this trend, the industry is focusing on innovative technology development and certification and rural markets that have quality wind resources and high electric retail rates, while keeping the 2021 end date of the Residential Renewable Energy Tax Credit in mind as it may cause disruption to sales and project planning. As more customers are using large-scale turbines (i.e., greater than 1 MW) behind-the-meter and to support local grid loads, the use of mid-size turbines (101 kW to 1 MW) is becoming less common. A limited number of mid-size turbines are commercially available, which may account for the lower level of deployment but also may account for the use of refurbished turbines in this size sector. For example, the White Earth Tribe in Minnesota installed a refurbished Zond 750-kW turbine in 2018, which was one of the two mid-size turbine installations that were completed that year. Large-scale turbine projects, particularly for government, commercial and industrial, and utility customers, are likely to continue to dominate distributed wind capacity deployment.

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# Appendix A: Wind Turbine Manufacturers and Suppliers

This report reflects 2018 sales and installations from the manufacturers and suppliers listed in Table A.1. Other companies that provided information, or only had sales outside of the United States, are recognized in the "Acknowledgments" section.

**Table A.1. Wind Turbine Manufacturers and Suppliers**

| Manufacturer | Model Names | Headquarters |
|---|---|---|
| Small Wind Turbines (up through 100 kW) | | |
| APRS World, LLC | WT10, WT14 | Minnesota |
| Bergey WindPower | Excel 10 | Oklahoma |
| Eocycle Technologies, Inc. | EO20 / EO25 | Canada |
| Hi-VAWT Technology Corporation | DS300, DS3000 | Taiwan |
| Northern Power Systems (NPS) | NPS 100-24 | Vermont |
| Primus Wind Power | AIR 30, AIR X Marine, AIR 40, AIR Breeze, AIR Silent X | Colorado |
| QED Wind Power | PHX20 | Arizona |
| XANT | XANT M-21 | Belgium |
| Wind Turbines Greater than 100 kW in U.S. Distributed Wind Projects | | |
| EWT Americas | DW-52-900 | Netherlands |
| GE Renewable Energy | 1.7-100, 1.85-82.5, 2.0-116, 2.3-116 | United States |
| Goldwind | GW87/1500, GW 3MW(S) | China |
| VENSYS | VENSYS 82, VENSYS 120 | Germany |
| Zond (Refurbished) | Unknown | Unknown |

# Appendix B: Methodology

The Pacific Northwest National Laboratory (PNNL) team issued data requests to 370 distributed wind manufacturers, suppliers, developers, installers, operations and maintenance (O&M) providers, state and federal agencies, utilities, and other stakeholders. The team compiled responses and information from these data requests (with sources listed in the "Acknowledgments" section) to tabulate the deployed United States and exported distributed wind capacity and associated statistics as of the end of 2018. The detail with which the stakeholders responded to the data requests varied, thus the team includes sample sizes and qualifications with certain analysis presentations as needed.

A project dataset was created to capture all known projects installed in 2018. For distributed wind projects using turbines greater than 100 kW, the PNNL team reviewed the American Wind Energy Association's (AWEA) database and assessed projects on a per-project basis to determine if they met the U.S. Department of Energy's definition of distributed wind and therefore should be included in the distributed wind project dataset. For projects using small wind turbines (up through 100 kW), project records were obtained directly from manufacturers and suppliers, O&M providers, utilities, and agencies through emails and/or phone interviews.

All records were compiled in the project dataset with a row for each 2018 project reported. Sales and installation reports from manufacturers, dealers, and developers were cross-referenced with records provided by agencies and installers to identify and combine information from duplicate records. Notes were made in instances of conflicting information (e.g., incentive award amounts, installed costs, and installation dates) as to which sources were used. Small wind turbine sales with project-specific records were added to the project dataset; however, most of the 2018 small wind units sold were not tracked at the project level.

The PNNL team also reviewed and cross-checked wind project listings published by Open Energy Information, Federal Aviation Administration, U.S. Wind Turbine Database, and U.S. Energy Information Administration. Identified projects not already in the AWEA records or reported by manufacturers or agencies were verified and added to the 2018 project dataset. Projects reported for 2018 were cross-checked against previous records to avoid double counting.

For small wind turbines, this study reports capacity and unit figures for the same calendar year as the reported sales by the manufacturers and suppliers for the purpose of tallying annual deployed capacity. Most manufacturers report precise units sold, but at least one manufacturer provides estimated units sold because the company's less than 1-kW size units are shipped in bulk to distributors. Some installations occur after the calendar year that the wind turbines were sold, so sales and projects are recorded separately. A U.S. sales presence is defined as manufacturers and suppliers documenting at least one sale in the United States in 2018.

Cross-referencing data sources allows for greater certainty, but a data gap remains with respect to the tally of units and capacity deployed per state compared to the small wind sales records because the majority of small wind units sold are not tracked on a project-level basis. Project records are used to allocate capacity values across the states.

This *2018 Distributed Wind Market Report* is the DOE's seventh annual report. Project records from this, and past years, have been consolidated to produce a master project dataset.[29] When known, decommissioned turbines are removed from the dataset, but the cumulative figures principally represent annual capacity additions, rather than confirmed operating installations. Capacity allocations by state by year therefore may differ slightly from report to report.

Incentive payments and reports can lag or precede sales reports. This report tallies and reports incentive payments for the year in which they were granted, regardless of the time of installation, using the best information available at the time of publication. Projects that receive U.S. Department of Agriculture Rural Energy for

[29] Master project dataset: https://wind.pnnl.gov/dw_download/logon.aspx.

America Program grants are recorded in the year the grant is awarded, although they may not be installed for up to two years after the grant. Project records in the master project dataset are updated accordingly when new information is available.

The PNNL team documents installed costs primarily from installers, developers, agencies, public sources such as press releases and news articles, and a few private sources. For the projects using turbines greater than 100 kW, the PNNL team and the Lawrence Berkeley National Laboratory team, authors of the annual *Wind Technologies Market Report*, share and cross-reference installed cost data for distributed wind projects. In some instances, installed cost figures are estimated based on reported incentive values. The PNNL team estimated the 2018 investment values using this reported installed cost data and made estimates based on past projects and PNNL's *Benchmarking U.S. Small Wind Costs* report when needed.

The LCOE calculations in Section 7.0 used the following formula:[30]

$$LCOE = ((FCR \times ICC) + O\&M) \div AEPnet$$

where FCR = fixed charge rate = (0.05), assuming a 25-year loan at 1.3% interest and a 35% tax rate
ICC = installed capital cost ($)
AEPnet = net annual energy production (kWh/yr)
O&M = annual O&M cost ($)

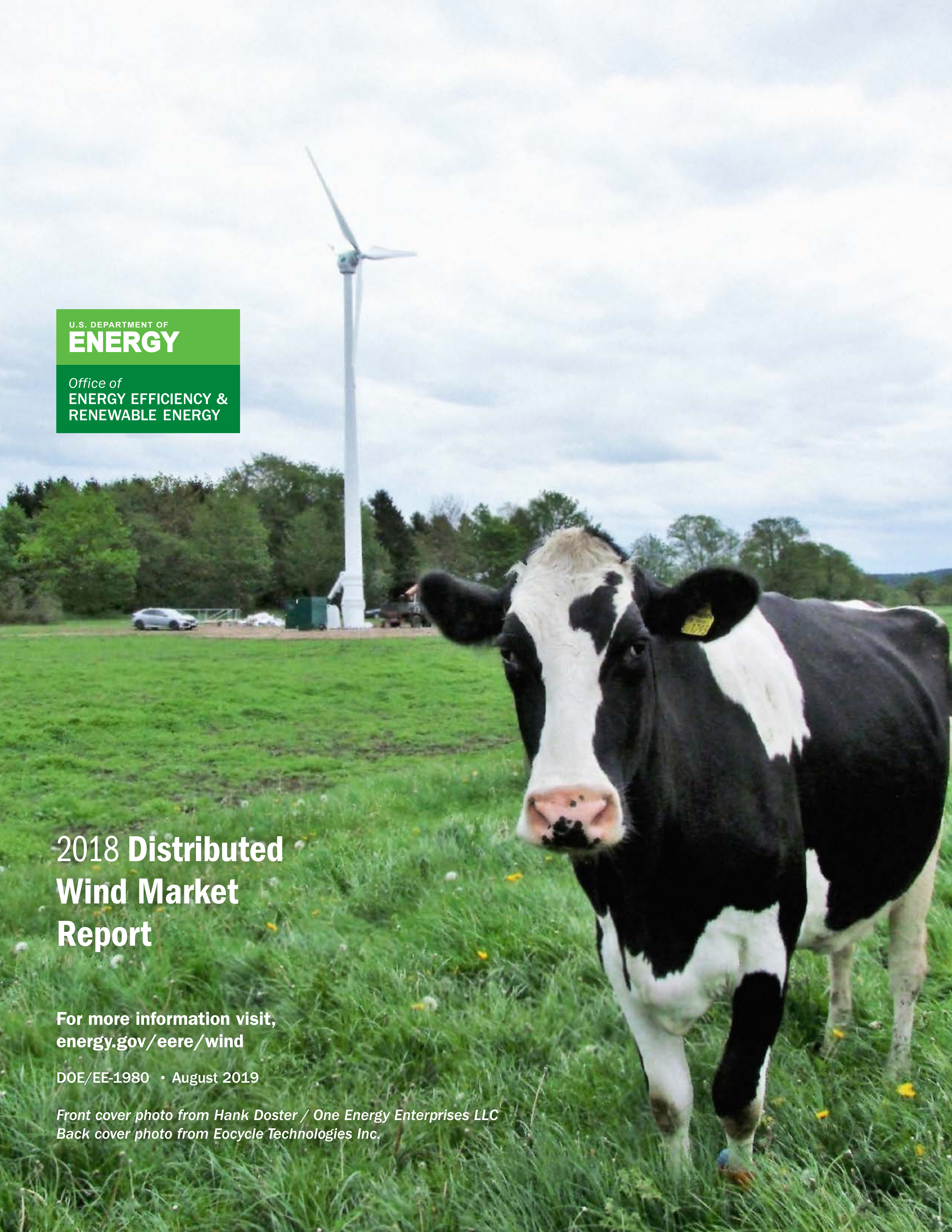
As the type of financing used and any related sensitivity analysis is not the focus of the LCOE analysis for this report, applying the same financing assumptions uniformly to the projects is appropriate.

Table B.1 presents the rated or referenced capacities used in the small wind capacity factors, levelized costs of energy (LCOE), maintenance costs per kilowatt, and installed costs per kilowatt calculations for the small wind turbines.

**Table B.1. Turbine Models in Small Wind Dataset**

| Turbine Model | Rated or Referenced Power at 11 m/s (kW) | Nominal Turbine Capacity (kW) | Rated or Referenced Power Source |
|---|---|---|---|
| Bergey Excel 6 | 6 | 5.5 | Small Wind Certification Council (SWCC) full certification to AWEA 9.1-2009 Standard (expired) |
| Bergey Excel 10 | 8.9 | 10 | SWCC full certification to AWEA 9.1-2009 Standard |
| Dakota Turbines DT-25 | 23.9 | 25 | SWCC full certification to AWEA 9.1-2009 Standard |
| Endurance E-3120 | 56 | 50 | SWCC power performance certification to IEC 61400-12-1 (expired) |
| Endurance S-343 | 5.4 | 5 | SWCC full certification to AWEA 9.1-2009 Standard (expired) |
| Gaia GW 133-11 | 10.7 | 11 | United Kingdom Microgeneration Certification Scheme certification to IEC 61400-12-1 as of January 2015 |
| Northern Power Systems (NPS) 100-21 | 79 | 100 | DNV power performance certification to IEC 61400-12-1 |
| NPS 100-24 | 90 | 100 | Manufacturer's power curve |
| Osiris 10 | 9.8 | 10 | Intertek full certification to AWEA 9.1-2009 Standard (expired) |
| Pika T701 | 1.5 | 1.7 | SWCC full certification to AWEA 9.1-2009 Standard (expired) |
| Southwest Windpower/ Xzeres Skystream 3.7 | 2.1 | 2.4 | SWCC full certification to AWEA 9.1-2009 Standard |
| Sonkyo Energy | 3.5 | 3.2 | Intertek full certification to AWEA 9.1-2009 Standard (expired) |
| Xzeres 442SR | 10.4 | 10 | SWCC full certification to AWEA 9.1-2009 (expired) |

[30] NREL's LCOE formula includes a levelized replacement cost that has been excluded here.



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