U.S. DEPARTMENT OF
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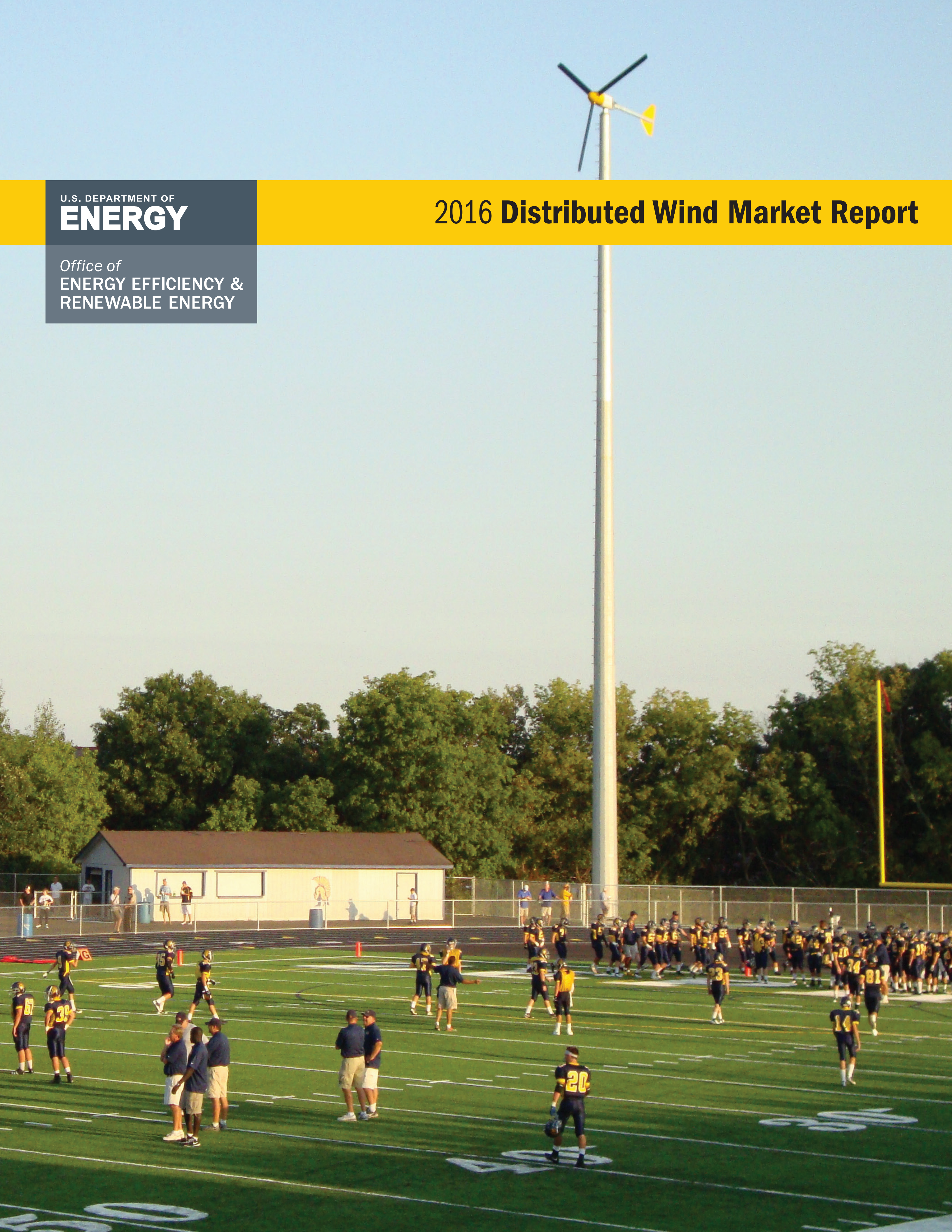
2016 **Distributed Wind Market Report**



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FOR MORE INFORMATION ON THIS REPORT:

Alice Orrell, PE
Energy Analyst
509-372-4632
alice.orrell@pnnl.gov

2016 Distributed Wind Market Report

Authors:
Alice C Orrell
Nikolas F Foster
Scott L Morris
Juliet S Homer

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Pacific Northwest National Laboratory
Richland, Washington 99352

EXECUTIVE SUMMARY

From 2003 through 2016, a total of 992 MW in cumulative capacity from over 77,000 wind turbines was deployed in distributed applications across all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands (USVI), and Guam. In 2016, 25 states and Guam added a combined 45.4 MW of new distributed wind capacity, representing 2,585 turbine units and $163 million in investment. Of the 45.4 MW, 43 MW is from turbines greater than 100 kW, and 2.4 MW is from small wind (turbines up through 100 kW). Rhode Island, Minnesota, and Massachusetts led the United States in new distributed wind power capacity in 2016.

The 43 MW from turbines greater than 100 kW installed in distributed applications in 2016 represents $149 million in investment, an increase from 23.7 MW and $81 million in 2015. The increase was driven mainly by the installation of multiple large (greater than 1 MW) turbine projects, mostly installed behind the meter, or remote net metered, for industrial operations and municipalities.

The 2.4 MW of small wind deployed in the United States in 2016 represents 2,560 units and more than $14 million in investment. This continued the downward trend of recent years and was the lowest small wind annual capacity addition recorded since this annual report was started in 2012. However, while overall capacity is down—driven by the decrease in sales of units sized from 11 kW to 100 kW —sales of units 10 kW and less increased from 2015.

Since 2012, the number of small wind turbine manufacturers, both operating and participating in the U.S. market, has decreased. U.S. small wind manufacturers accounted for 98% of 2016 U.S. domestic small wind sales; non-U.S.-based small wind turbine manufacturers continue to have limited sales in the United States and typically focus on international markets. New York led the nation for small wind capacity deployment in 2016, accounting for 25% of documented small wind capacity for the year.

As certification requirements are becoming increasingly common across the globe, small wind manufacturers continue to pursue the certification process for their turbine models. Certification is also consistent with industry and Department of Energy goals to promote the use of proven technology; raise its competitiveness; and increase consumer, government agency, and financial institution confidence and interest in distributed wind.

Three new small wind turbine models were certified in 2016. A total of 15 different small wind turbine models are fully certified to the American Wind Energy Association (AWEA) Standard 9.1-2009 as of July 2017, whereas no turbine models were certified in 2010. Three medium wind turbine models have published power performance and acoustics certifications to International Electrotechnical Commission (IEC) 61400-12-1 (power) and IEC 61400-11 (acoustics).

In January 2016, United Wind, a distributed wind leasing company, announced that it had secured $200 million in project equity capital from Forum Equity Partners to expand its lease program. A year later, United Wind announced that it had purchased 100 Excel 10 Bergey WindPower wind turbines, the largest order ever—by number of units—for either company.

In December 2016, One Energy Enterprises LLC secured $80 million in financing from Prudential Capital Group, signaling institutional capital acceptance of One Energy Enterprises' approach to providing distributed wind to industrial and commercial customers.

Other highlights of the report include:

- U.S.-based small wind turbine manufacturers continued to favor U.S. supply chain vendors for most of their wind turbine components. Self-reported domestic content levels for 2016 ranged from 80% to 100%.

- U.S. small wind turbine manufacturers continued to focus on international markets as a source of revenue. While exports doubled from 2014 to 2015, exports in 2016 were back to a level comparable with 2014 at 10.3 MW with an estimated value of $62 million from six manufacturers.

- Reflecting the increase in sales of units 10 kW and less in size, an estimated 95% of turbine units in 2016 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, and military sites. However, grid-tied wind turbines accounted for nearly 99% of the annual distributed wind capacity (in terms of MW).

- Based on small wind turbine manufacturers' reports, the overall capacity-weighted average installed cost for small wind turbines sold in the United States in 2016 was $5,900/kW. After slightly declining the past three years, this cost metric has increased slightly from $5,760/kW in 2015.

- Based on surveys of international government and industry publications, total global small wind installed cumulative capacity was estimated to be at least 1.4 GW in 2016.

- The top three U.S. small wind turbine manufacturers, based on 2016 sales in terms of capacity (MWs of domestic sales and exports), in order were Northern Power Systems of Vermont, Xzeres Wind of Oregon, and Bergey WindPower of Oklahoma.

- The combined value of federal, state, and utility incentives given for distributed wind projects in 2016 was $12.8 million (excluding repaid loans, the federal investment tax credit, and federal depreciation). This reflects a relatively modest increase from the $10.6 million of 2015 funding awards, while still being significantly lower than in the preceding years, when funding levels fluctuated between $100 million (2012), $15.4 million (2013), and $20.4 million (2014).

- The overall number of wind turbine manufacturers supplying turbines for distributed wind projects has contracted significantly since 2012. In 2016, reported U.S. distributed wind projects encompassed 29 different wind turbine models ranging from 160 W to 2.3 MW from 17 manufacturers. This is comparable to 2015, during which U.S. distributed wind projects used 24 different wind turbine models ranging from 160 W to 2.85 MW from 15 manufacturers and suppliers, but a decline from the peak of 74 different turbine models from 30 manufacturers and suppliers in 2012.

- For documented projects in 2016, residential and agricultural installations accounted for the majority of 2016 projects (34% and 29%, respectively), but only for 7% of the total distributed wind capacity installed in 2016. Institutional projects, mainly utilities and schools, accounted for 64% of the distributed wind capacity installed in 2016.

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ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
AWEA	American Wind Energy Association
BEWT	built-environment wind turbine
CIP	Competitiveness Improvement Project
DECC	Department of Energy and Climate Change
DOE	U.S. Department of Energy
EIA	Energy Information Administration
ft	feet
FIT	feed-in-tariff
GE	General Electric
GW	gigawatt
IEC	International Electrotechnical Commission
IRS	Internal Revenue Service
ITC	investment tax credit
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of energy
m	meter
m^2	square meter
MACRS	Modified Accelerated Cost-Recovery System
MW	megawatt
MWh	megawatt-hour
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
PNNL	Pacific Northwest National Laboratory
PPA	power purchase agreement
PTC	production tax credit
PV	photovoltaic
REAP	Rural Energy for America Program
REC	renewable energy certificate
RPS	renewable portfolio standard
USDA	U.S. Department of Agriculture
USVI	U.S. Virgin Islands
VAWT	vertical-axis wind turbine
W	watt

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1.0 Introduction

The U.S. Department of Energy's (DOE's) annual Distributed Wind Market Report provides stakeholders with statistics and analysis of the market along with insights into its trends and characteristics. By providing a comprehensive overview of the distributed wind market, this report can help plan and guide future investments and decisions by industry, utilities, federal and state agencies, and other interested parties.

Distributed wind systems generate electricity and are defined by a project's location relative to end-use and power distribution infrastructure, rather than turbine or project size. Distributed wind includes the following:

- Wind energy systems—either off-grid[1] or grid-connected—at homes, farms and ranches, businesses, public and industrial facilities, or other sites to offset all or a portion of the local energy consumption at or near those locations, or

- Systems connected directly to the local grid[2] to support grid operations and local loads.

Distributed wind is differentiated from wholesale power generated at large wind farms and sent via transmission lines to substations for distribution to loads and distant end-users.

Grid-connected distributed wind systems can be located on the distribution grid or on the customer side of the meter, either physically or virtually. Virtual (or remote) net metering is a billing arrangement that allows multiple energy customers to receive net-metering credit from a shared on-site or remote renewable energy system within the customers' utility service area, as if it was located behind the customer's own meter (Freeing the Grid 2015).

Because the definition of distributed wind depends on where the project is located and how the power is used, the distributed wind market includes wind turbines and projects of many sizes. For example, distributed wind systems can range from a less than 1 kilowatt (kW)[3] off-grid wind turbine at a remote cabin or well head, to a 10 kW wind turbine at a home or farm, to several multi-megawatt (MW) wind turbines at a university campus, manufacturing facility, or other large facility.

1.1 Purpose of Report

The annual Distributed Wind Market Report documents, analyzes, and characterizes the differences and trends unique to distributed wind, including but not limited to, costs, number of deployments, performance and capacity factors, types of turbines used, customer type, domestic and international markets, and market drivers and barriers. Other market reports, such as DOE's annual Wind Technologies Market Report (Wiser and Bolinger 2017), concentrate only on U.S. wind projects using turbines greater than 100 kW. This report specifically analyzes the distributed wind sector of the market and details the annual U.S. small wind market to make year-to-year comparisons, measure market growth, and identify trends in the industry.

The report provides key information on current market conditions and regulatory environments that can help stakeholders increase the cost competitiveness of distributed wind systems and build better turbines and components, leading to improved grid integration and increased customer and utility confidence in distributed wind systems.

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 based on nominal, or nameplate, capacity:

- Small wind turbines up through 100 kW,

- Mid-size wind turbines 101 kW to 1 MW, and

- Large-scale wind turbines greater than 1 MW.

The U.S. Internal Revenue Service (IRS) defines small wind as up through 100 kW for the purpose of federal investment tax credit (ITC) eligibility (see Section 4.1.2). For certification purposes, international and domestic standards define small wind turbines as having rotor swept areas up to 200 m^2 (approximately 50 to 65 kW) and medium wind turbines as having rotor swept areas greater than 200 m^2. This report uses the term mid-size to denote a specific turbine size range, 101 kW to 1 MW; therefore, medium and mid-size are not interchangeable terms.

1.3 Data Collection and Analysis Methodologies

To produce this report, Pacific Northwest National Laboratory (PNNL) issued data requests to distributed wind manufacturers, 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

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[1] Off-grid wind turbine systems directly serve on-site loads and typically include battery backup or other energy storage as they are not connected to the local distribution grid.

[2] The local grid is defined as distribution lines with interconnected electric load(s), typically at a voltage of 34.5 kV or below.

[3] 1 GW = 1,000 MW; 1 MW = 1,000 kW; 1 kW = 1,000 W.

in 2016 identified in the data request process. For distributed wind projects using turbines greater than 100 kW, the PNNL team reviewed the American Wind Energy Association's (AWEA's) database and assessed these projects on a per project basis to determine if they met DOE's definition of distributed wind and should therefore be included in the distributed wind project dataset. Small wind turbine sales for which project-specific records from manufacturers and suppliers, O&M providers, utilities, and agencies were obtained in the data request process were added to the project dataset, but many 2016 small wind units sold were not tracked at the project level, such as off-grid turbine units, and are therefore not included in the project dataset. The project dataset is used to allocate capacity values across the 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).

A small wind sales dataset was also created based on manufacturers' sales reports. The total number of small wind turbine units and capacity deployed domestically and abroad, and their estimated investment values, are from this small wind sales dataset. For small wind, this study reports capacity figures for the same calendar year as the reported sales by the manufacturers and suppliers for the purpose of tallying annual deployed capacity. For turbines greater than 100 kW, the annual deployed capacity is the sum of the distributed wind projects from the AWEA database for the calendar year.

More details about the data collection process and analysis methodology are in Appendix B.

This 1.7-kW Pika Energy T701 wind turbine is at a residence in Maine.
Photo credit: Pieter Huebner / Off-Grid Enterprises

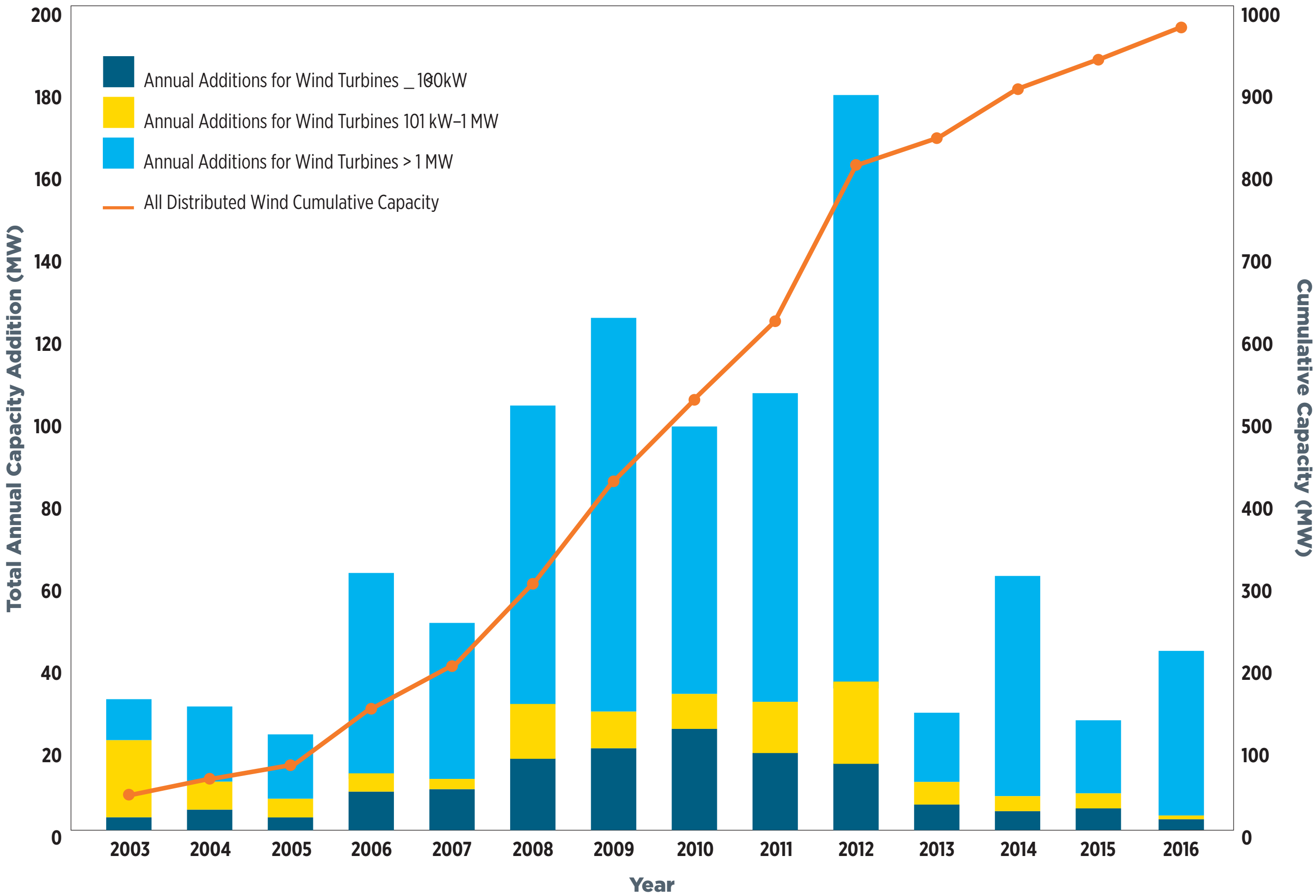

Figure 1. U.S. distributed wind capacity

2.0 U.S. Distributed Wind Deployment

Between 2003 and the end of 2016, over 77,000 wind turbines were deployed in distributed applications across all 50 states, Puerto Rico, the U.S. Virgin Islands (USVI), and Guam, totaling 992 MW[4] in cumulative capacity (Figure 1).[5] In 2016, 25 states and Guam added 45.4 MW of new distributed wind capacity, representing 2,585 units and $163 million in investment.

In 2016, 2.4 MW of small wind was deployed in the United States, representing 2,560 units and over $14 million in investment. Driven by a decrease in available incentive programs and continued competition from low-cost solar PV, this continues the downward trend of recent years and is the lowest annual small wind capacity value since the inauguration of this report in 2012. However, while overall capacity is down, unit sales have increased from 2015, mainly in the 10 kW and lower size range.

There were 8,203 MW of wind project installations in 2016 using turbines greater than 100 kW (AWEA 2017). Of this 8,203 MW, PNNL considers 43 MW to meet the definition of distributed wind, representing $149 million in investment. In 2015, this figure was 23.7 MW out of the overall 8,598 MW of wind capacity installed. This increase from 2015 is due in part to an increase in large, behind-the-meter turbine units powering industrial operations and municipalities.

2.1 Top States for Distributed Wind: Annual and Cumulative Capacity

New distributed wind projects were documented in 25 states and Guam in 2016 (Figure 2) and have been documented in all 50 states, the District of Columbia, Puerto Rico, the USVI, and Guam since 2003 (Figure 3).[6]

[4] This cumulative total reflects capacity adjustments made to prior years, namely projects in Alaska and Utah that were inadvertently excluded in previous years' reports.

[5] The data presented in the figures are provided in an accompanying data file available for download at http://energy.gov/eere/wind/downloads/2016-distributed-wind-market-report.

[6] Since 2015, PNNL has been building a master project dataset, available at http://wind.pnnl.gov/dw_download/logon.aspx. The state map allocations and top state designations have been adjusted to reflect this project dataset, and moving forward, reported wind capacity data for each year and each state will be updated as information changes.

Rhode Island, Minnesota, and Massachusetts led the United States in new distributed wind power capacity in 2016 as a result of large behind-the-meter and remote net metered turbine projects, and large size projects serving local loads. With the New York State Energy Research and Development Authority (NYSERDA) incentive program, New York led the nation for small wind capacity deployment in 2016, accounting for 25% of the documented small wind capacity for the year.

Texas, Minnesota, and Iowa are the top states for overall distributed wind capacity deployed since 2003 (Figure 4). Iowa, Nevada, and Alaska are the top states for cumulative installed small wind capacity (Figure 5).

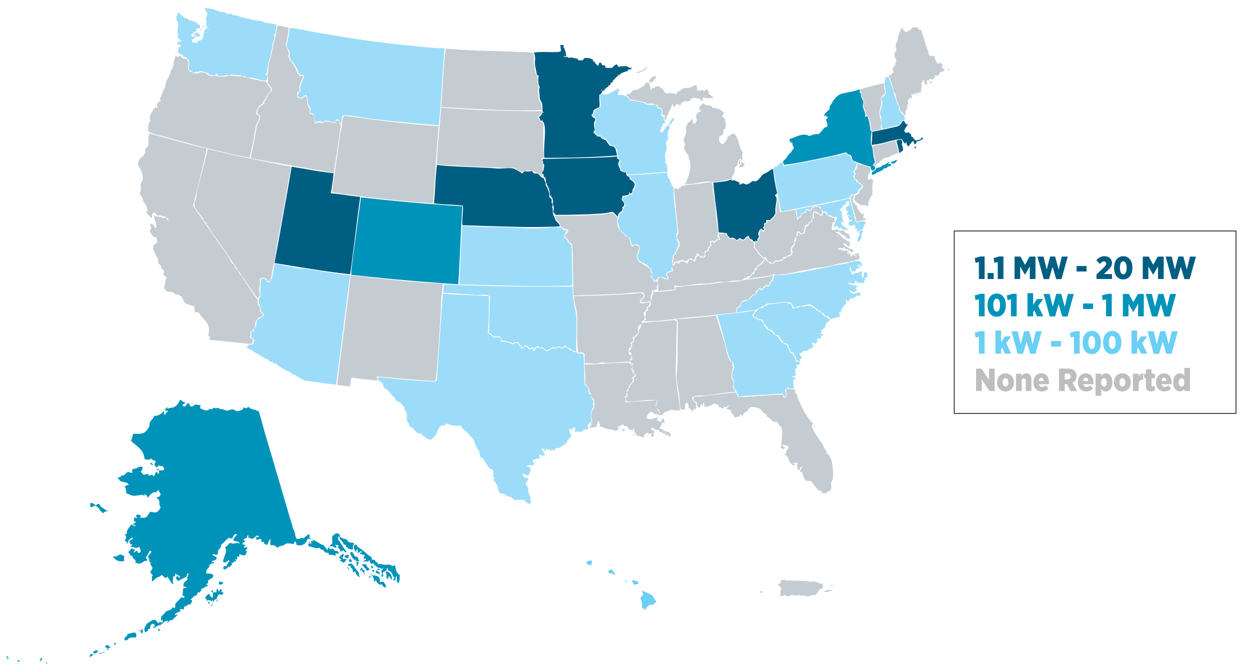

Figure 2. 2016 U.S. distributed wind capacity additions by state

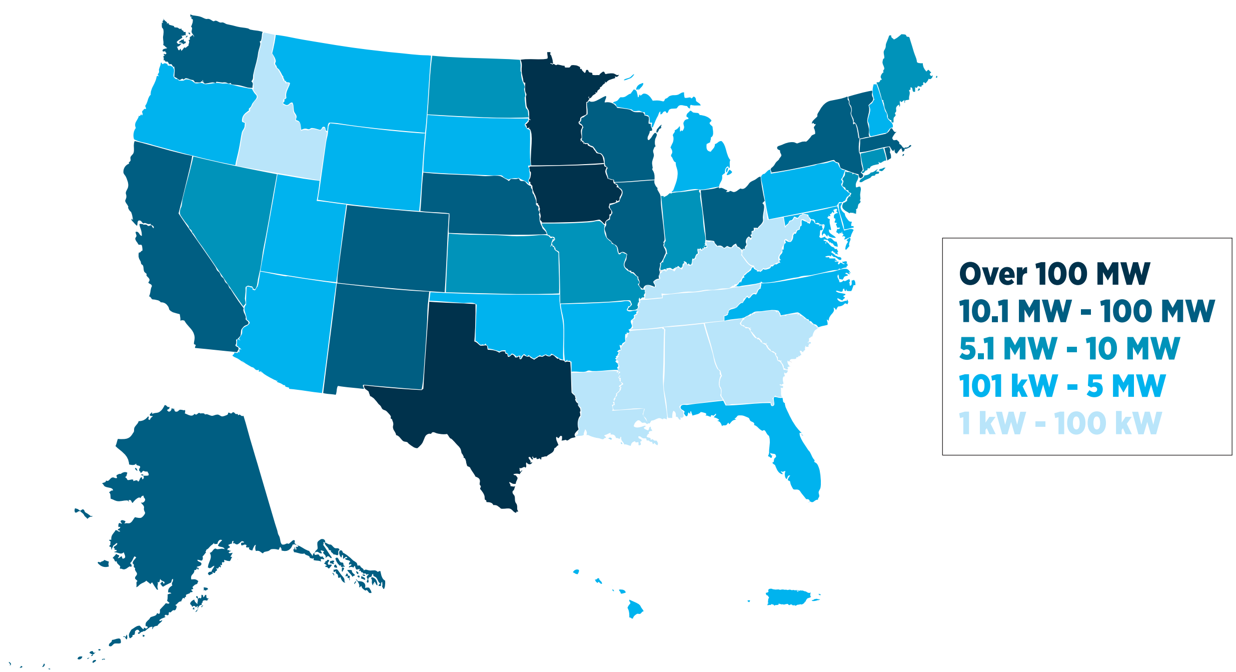

Figure 3. Cumulative U.S. distributed wind capacity by state, 2003–2016

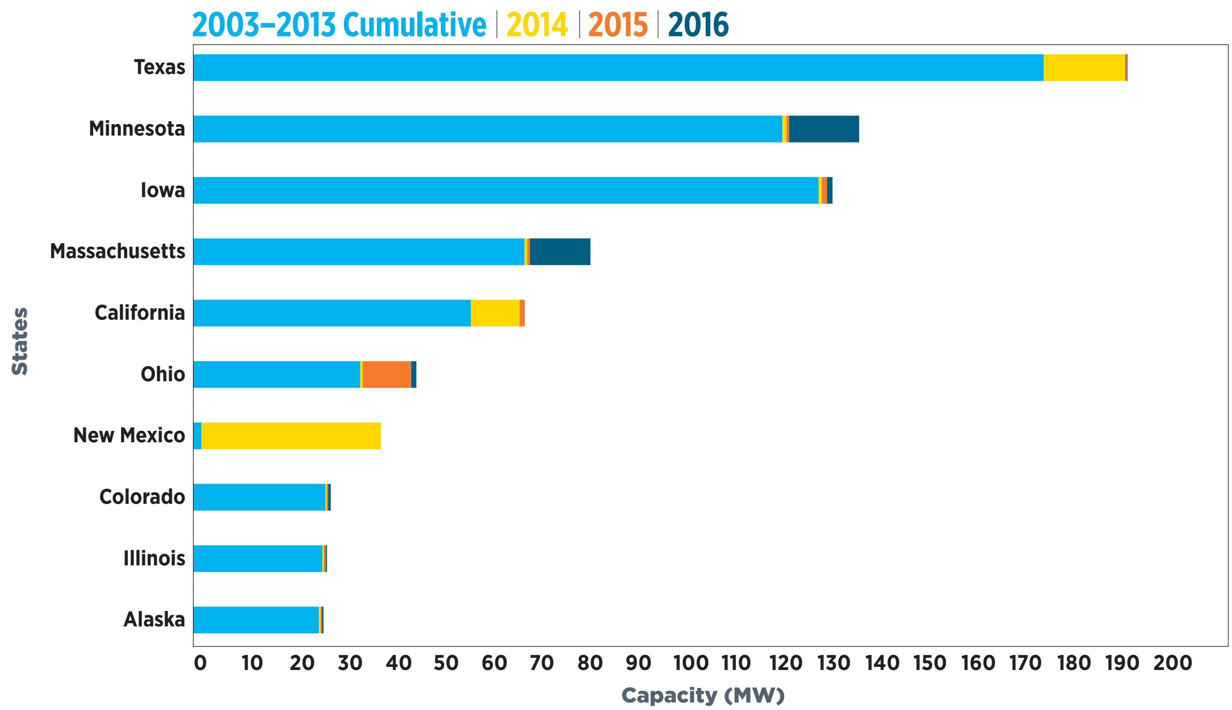

Figure 4. Top states for distributed wind capacity, 2003–2016

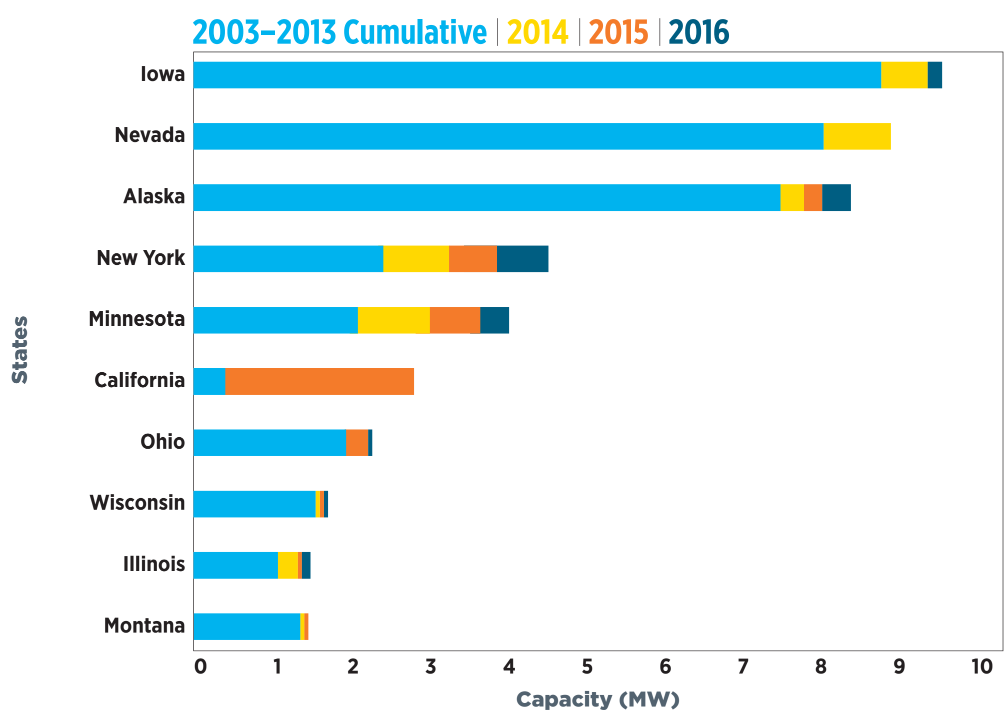

Figure 5. Top states for small wind capacity, 2003–2016

3.0 Domestic Sales, Imports, Exports, and the Global Market

The 12 small wind turbine manufacturers with a 2016 U.S. sales presence accounted for in this report consist of nine domestic manufacturers headquartered in eight states (Colorado, Maine, Minnesota, New York, North Dakota, Oklahoma, Oregon, and Vermont) and three importers.

Non-U.S.-based small wind turbine manufacturers continue to have limited sales in the United States, as shown in Figure 6. Of the six foreign manufacturers who replied to PNNL's data request, only three reported sales in the United States in 2016—Hi-VAWT Technology Corporation (Taiwan), Kingspan Environmental Limited (Ireland), and Potencia Industrial (Mexico). In 2015, two other foreign manufacturers reported sales in the United States—Gaia-Wind (United Kingdom) and Sonkyo Energy (Spain). This suggests that no single foreign small wind manufacturer has a strong, consistent presence in the U.S. distributed wind market.

Since 2012, the small wind industry has contracted and the number of small wind turbine manufacturers, both operating and participating in the U.S. market, has decreased. In 2012, 31 companies reported U.S. sales; in 2016 only 12 companies reported sales in the United States. Some small wind manufacturers do not have consistent sales from year to year, some go out of business, and some—particularly foreign manufacturers—focus on other countries with policies supportive of distributed wind.

When small wind turbine manufacturers go out of business, service providers, installers, and other manufacturers sometimes step in to provide O&M for the orphaned turbines, retrofit the existing towers and foundations with other turbine models, or take over the manufacturing of the turbines.

In 2016, at least five small wind turbine manufacturers went out of business or changed hands:

- On January 1, 2016, Xzeres Corporation announced it had been acquired by Ravago, a polymer distributer and manufacturer (Xzeres 2016). Xzeres, located in Oregon, is now a wholly owned subsidiary of Ravago Americas, which is headquartered in Florida. The parent company is based in Belgium.

- Endurance Wind Power (Canada) filed bankruptcy in November 2016. Mid-size turbine manufacturer and service company, EWT (The Netherlands) has offered service arrangements, and mCloud (United States), a cloud service and secure mobile technology company, has offered monitoring arrangements to Endurance turbine owners.

- Black Island Wind Turbines (United States) was sold to APRS World (United States), a manufacturer of off-grid turbines, who will add the 3 kW Black Island turbine model to its manufacturing line.

- Wind Turbine Industries Corporation (United States) sold the 20 kW Jacobs 31-20 turbine model to AquaGen, a domestic installer and service provider who likely will provide service and manufacture replacement parts for existing Jacobs installations, but will not manufacture new Jacobs turbines.

- On September 6, 2016, UGE International Ltd. (United States) announced the sale of its wind turbine business line to a former UGE manufacturing manager who operates the new wind-focused entity as V-AIR Wind Technologies (UGE 2016).

The top three U.S. small wind turbine manufacturers, based on 2016 sales in terms of capacity (MWs of domestic sales and exports), in order were Northern Power Systems of Vermont, Xzeres Wind of Oregon, and Bergey WindPower of Oklahoma. Although its combined capacity sales value is lower than these manufacturers, Primus Wind Power, which provides a range of 160 W and 400 W off-grid turbine models, had record unit sales in 2016. Primus sold mainly to the oil and gas industry, telecom installations in international markets, and remote U.S. military applications both inside and outside of the United States. Six U.S. small wind turbine manufacturers exported turbines. All U.S. small wind manufacturers with sales included in this report are listed in Appendix A.

With respect to turbines greater than 100 kW, seven different models for 13 distributed wind projects were supplied by five manufacturers and suppliers[7] in 2016. These five were U.S.-based[8] manufacturer, General Electric (GE) Renewable Energy and the following four importers—Gamesa (Spain), Goldwind (China), Vensys (Germany), and Vergnet (France). Similar to the small wind industry, the number of mid-size and large turbine manufacturers and suppliers with installations in the United States has contracted since 2012. In 2012, 27 manufacturers supplied 33 different mid-size and large-scale turbine models for 69 distributed wind projects.

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

[8] U.S.-based means the manufacturer or supplier is headquartered in the United States. Actual manufacturing and component source locations can be domestic or international.

3.1 Domestic Sales

The 2.4 MW of small wind sales recorded in 2016 represent 2,560 units and over $14 million in investment. This continues the downward trend of deployed capacity of recent years. A total of 4.3 MW of small wind was deployed in 2015 (1,695 units and a $21 million investment), 3.7 MW in 2014 (1,600 units and a $20 million investment), and 5.6 MW in 2013 (2,700 units and a $36 million investment). No refurbished small wind turbine sales were reported for 2016.[9] U.S. small wind manufacturers accounted for 98% of the 2016 U.S. domestic small wind sales, as shown in Figure 6. Figure 6 shows annual domestic, export, refurbished, and import sales of small wind turbines.

A total of 43 MW of distributed wind capacity was installed in 2016 using turbines greater than 100 kW. While U.S. manufacturers dominate the small wind domestic sales, the mid-size and large-scale turbine markets rely more on imports. Four of the five manufacturers of turbines greater than 100 kW with installations in the United States in 2016 were non-U.S.-based representing 24.7 MW and 17 turbine units. A total of 18.3 MW and eight turbine units were from U.S.-based manufacturers.

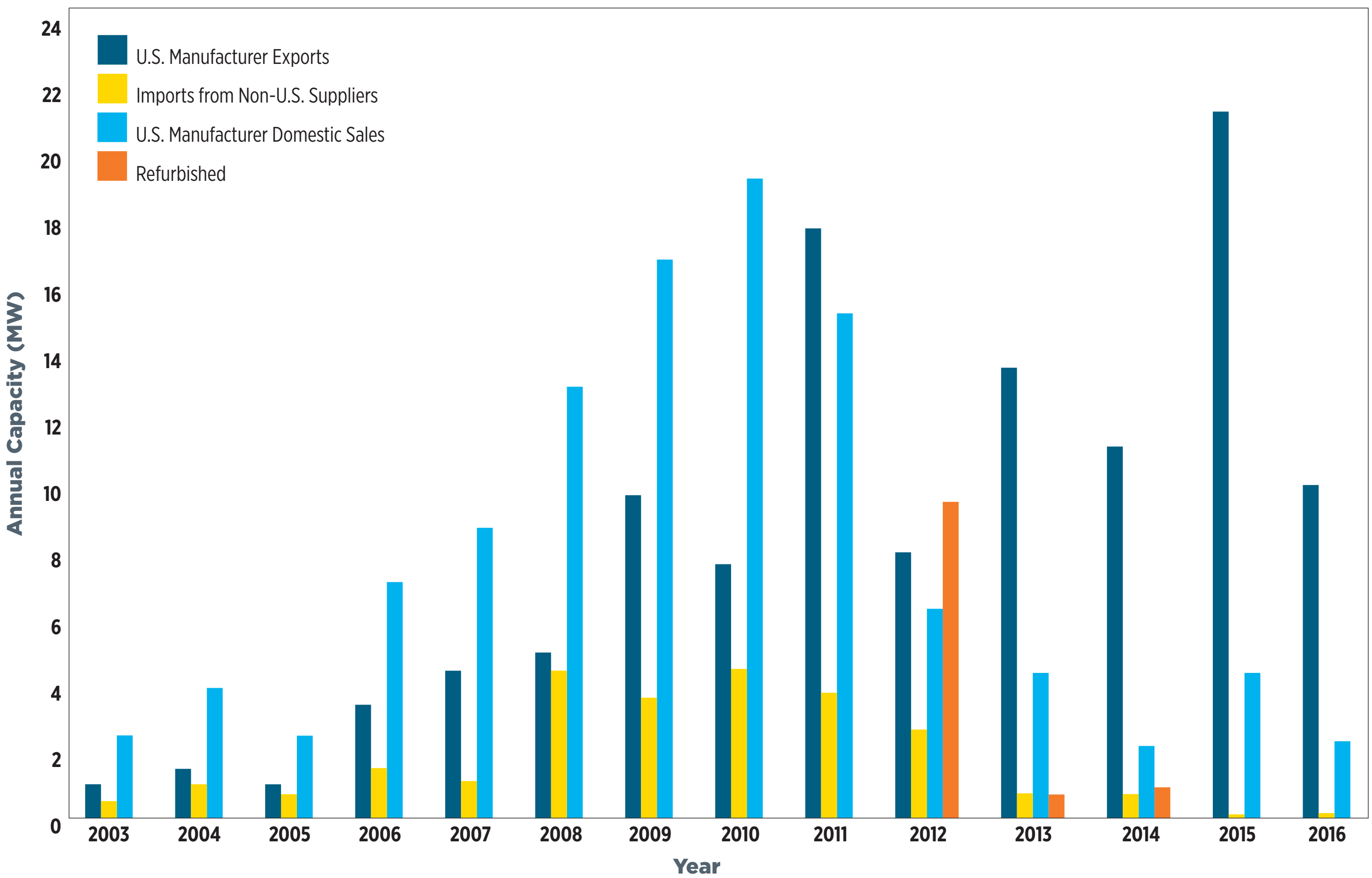

Figure 6. U.S. small wind turbine sales and exports, 2003–2016

[9] Most refurbished wind turbines sold in 2012 were installed in Nevada and received Section 1603 funding and NVEnergy incentive program funding; thus, the decrease in 2013 and 2014 and lack of reports in 2015 and 2016 are likely related to the lower NVEnergy incentive rates implemented in 2014 and the expiration of the Section 1603 cash grant program.

3.2 Imports

Reported sales in the United States from foreign small wind manufacturers continued to be low in 2016 with only three manufacturers reporting sales. All non-U.S.-based small wind manufacturers did report sales in other markets though, primarily Italy, the rest of Europe, Japan, and China. Non-U.S.-based small wind manufacturers report they are monitoring the policy and regulatory environment in the United States and other countries to determine market strategies and the potential for re-entry into the U.S. market.

The mid-size and large-scale markets continued to be supplied by mostly foreign manufacturers in 2016. GE Renewable Energy has been the only consistent U.S.-based manufacturer of large turbines used in distributed wind projects for the past five years. Gamesa, Vestas, Goldwind, and Vergnet wind turbines have been used in distributed wind projects more consistently than other models in the past five years. Similar to the small wind sector of the market, this mix, and the few number of players overall, suggests no single manufacturer has a strong position in the U.S. distributed wind market, although Goldwind is the sole turbine supplier for One Energy Enterprises LLC, a distributed wind project developer based in Ohio.

3.3 Exports

U.S. small wind turbine manufacturers continued to seek international markets as a source of additional revenue. The top reported export markets in terms of capacity were Italy, the United Kingdom, and Japan. While six U.S.-based small wind manufacturers exported 10.3 MW with an estimated value of $62 million in 2016, some manufacturers focused their sales in just one country, while others had a more evenly spread global reach. The 10.3 MW in 2016 is down from 2015 (21.5 MW from six manufacturers with a value of $122 million), but comparable to 2014 (11.2 MW from seven manufacturers with a value of $60 million). Figure 7 shows the primary reported countries that received U.S. small wind exports.

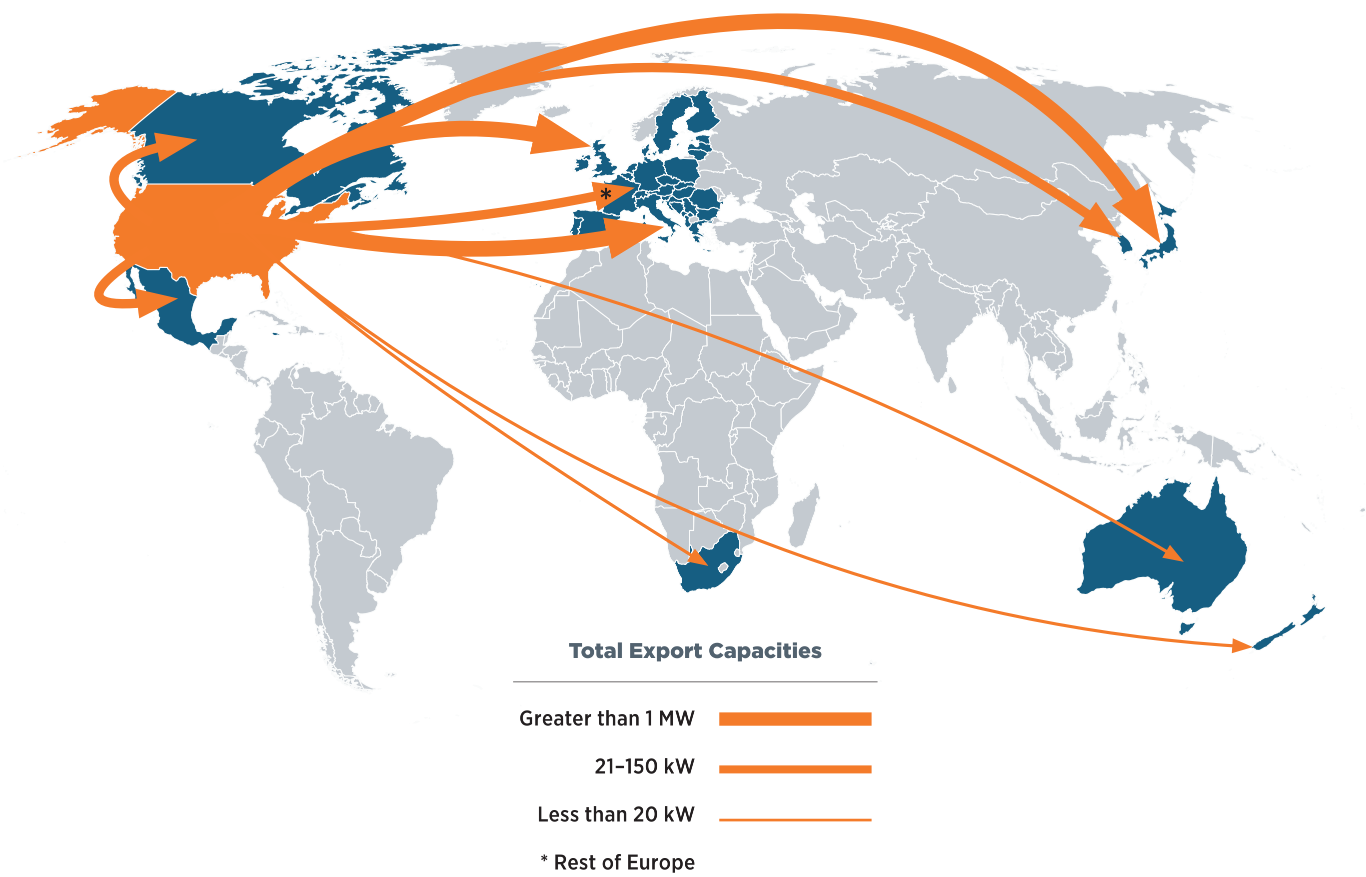

Figure 7. 2016 U.S. small wind capacity exports map

3.4 Global Small Wind Market

The 116 MW of new installed global small wind capacity reported in 2016 reflects a robust global demand for small wind. Yet looking at country data individually, several disparities emerge, driven by the different market policies and incentives. The new small wind capacity installed in Italy in 2016 more than doubled its cumulative capacity, and Japan's annual installations almost tripled from 2015 to 2016. At the same time, new installations in the other major markets of the United States, the United Kingdom, and China dropped significantly in 2016.

Based on surveys of international government and industry publications, PNNL calculates the cumulative small wind installed capacity in 11 surveyed countries at 1.3 GW, as shown in Table 1. The World Wind Energy Association has estimated that China, the United States, and the United Kingdom represent between 80% and 90% of the global small wind market (Gsänger and Pitteloud 2014, 2016). Based on this estimate and PNNL's surveys, total global installed cumulative capacity, accounting for countries not included in Table 1, is estimated to be at least 1.4 GW as of 2016.

Table 1. U.S. Small Wind and the Global Market[8]

	2013 (MW) Installations	2014 (MW) Installations	2015 (MW) Installations	2016 (MW) Installations	Cumulative (MW) Installations	Cumulative Year Range
China	75	72.6	*	45	835.7[a]	2002-2016
Japan	*	*	0.364	0.952	5.21[b]	as of 2016
South Korea	*	*	0.322	0.07	4.228[c]	as of 2016
UK	14.7	28.5	11.7	7.73	135.13[d]	as of 2016
Denmark	1.216	1.441	5.025	*	17.628[e]	1978-2015
Germany	*	0.264	0.298	2.25	28.5[f]	2010-2016
Italy	7.003	15.773	10.809	57.904	112[g]	2012-2016
United States	5.6	3.7	4.3	2.431	146.559	2003-2016
Brazil	0.029	0.023	0.11	0.038	0.201[h]	2013-2016
Australia	*	*	0.037	*	1.416[i]	2001-2015
New Zealand	*	*	*	*	0.185[j]	as of 2015
Total	103.52	122.28	32.97	116.38	1,286.729	

* Not Available
[a] China Wind Energy Equipment Association (CWEEA)
[b] Japan Small Wind Turbines Association
[c] Korea Wind Energy Industry Association; Korea Energy Agency
[d] www.gov.uk, Monthly MCS and ROOFIT degression statistics
[e] www.energinet.dk
[f] Bundesnetzagentur; Bundesverband Kleinwindkraftanlagen; 0-50 kW capacity
[g] www.assieme.eu; 0-250kW capacity
[h] www.aneel.gov.br
[i] www.cleanenergyregulator.gov.au
[j] Sustainable Electricity Association of New Zealand

3.5 Italy

With 58 MW of new capacity installed, small wind (defined in Italy as up to 250 kW in size) had a banner year in Italy in 2016. The close to six-fold increase in installations of small wind capacity, compared to 10.8 MW in 2015, can be attributed to the country announcing changes to its generous feed-in tariff (FIT) scheme that ranges between 0.11 and 0.25 Euro (13¢ and 29¢), per kWh.[10] The FIT is slated to decrease in June 2017 and expire in December of 2017 (GSE 2016). According to Italy's wind industry association, Associazione Italiana Energia Mini Eolica (ASSIEME), the impending end of the FIT accelerated the timeline of many projects so they could receive the funding while it was still available. The majority—71 MW—of the 112 MW of cumulative small wind capacity installed in Italy comes from turbines sized 40 to 60 kW. Turbines sized 100 to 250 kW make up 29 MW, the second largest portion of the cumulative small wind capacity (ASSIEME 2017).

[10] All exchange rates are as of June 29, 2017 from Google Finance.

These 100 kW Northern Power Systems NPS100 wind turbines are installed in Italy.
Photo credit: Northern Power Systems

3.6 Japan

In 2016, Japan added close to 1 MW of small wind capacity from 84 projects, compared to 364 kW from 39 projects installed in 2015. The general upswing in installations is also mirrored in the great increase of approved (but not yet installed) projects, which went from 312 projects representing 4.6 MW in 2015 to 1,790 projects representing close to 32 MW in 2016.

Even as the Japanese government's target share of electricity coming from wind power by 2030 remains at a modest 1.7%, the growth in 2016 speaks for the still growing potential of the Japanese market for small wind. Also, the generous FIT remained unchanged in 2016, with 55 Yen (49¢) per kWh for turbines sized less than 20 kW and 22 Yen (20¢) per kWh for turbines sized 20 kW and greater (METI 2016). U.S. and foreign manufacturers see the Japanese market as promising, yet challenging for new entrants given the country's strict interconnection standards and certification requirements for grid-connected turbines.

3.7 United Kingdom

In 2016, 7.7 MW of small wind capacity was installed in the United Kingdom, reflecting a continued decline from nearly 12 MW in 2015 and 28.5 MW in 2014. The drop in installations coincides with the changes to the United Kingdom's FIT scheme. In late 2015, 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 to100 kW. Further, the government decreased the incentive value for turbines sized up through 100 kW from 13.73 pence (18¢) to 8.61 pence (11¢) per kWh. After a total suspension of the program between January 15 and February 7, 2016 (DECC 2015, OFGEM 2017a), the FIT was reinstated in May 2016 at 8.39 pence (11¢) per kWh for wind systems sized up to 50 kW, and 4.95 pence (6¢) per kW for systems sized 50 to 100 kW (OFGEM 2017b).

3.8 China

China remains the global leader in terms of installed small wind capacity. In 2016, approximately 45 MW of small wind turbines were installed in China, reflecting a significant decrease from the 73 MW of capacity installed in 2014 and a continued decrease from the over 100 MW annual additions between 2009 and 2011 (CWEEA 2017). The decline in small wind installations correlates with a continued slump of the overall Chinese economy through much of 2016, as well as a slight reduction in the FIT for wind turbines from 0.49 and 0.61 Chinese Yuan (8¢ and 9¢) per kWh in 2015 to 0.47 and 0.60 Chinese Yuan (7¢ and 9¢) per kWh in 2016, depending on the wind resource of the area in which they are located (Stock 2016). Exports of Chinese small wind turbines also decreased between 2014 and 2016, with 29.2 MW of capacity exported in 2014 and 20 MW exported in 2016 (CWEEA 2017).

4.0 Policies, Incentives, and Market Drivers

Policy decisions, technology development, and economic conditions directly influence manufacturers, installers, and buyers of distributed wind turbines. From changes in federal and state incentive levels to innovations in technology and financing, these decisions and conditions impact the U.S. distributed wind market.

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 wind and other distributed energy resources. Incentive programs vary widely with respect to the amount of funding they provide, the total number of projects they support, and the length of time they are available.

Figure 8 provides the number of federal, state, and utility incentives[11] given in each state for distributed wind projects in 2016; the combined value of all awards equals $12.8 million.[12] This reflects a relatively modest increase from the $10.6 million of 2015 funding awards, while still being significantly lower than in the preceding years, when funding levels fluctuated between $100 million (2012), $15.4 million (2013), and $20.4 million (2014). In 2016, nine states offered incentive funding, compared to 10 states in 2015.

4.2 State Policies, Incentives, and Renewable Portfolio Standards

State policies impact the distributed wind market. Renewable portfolio standards, net metering, interconnection standards and guidelines, FITs, municipal or community choice aggregation, utility programs, and the availability of grants, rebates, performance incentives, and state tax credits can impact the cost effectiveness and uptake of distributed wind in a state.

Rhode Island, Minnesota, and Massachusetts are highlighted here to illustrate the different state and utility policies certain projects leveraged. Further, recent renewable portfolio standard (RPS) changes in Illinois, Maryland, Rhode Island, and Michigan are also discussed as these changes may impact distributed wind in these states in the near future.

4.3 Policy and Incentive Highlights

With 15 MW installed in 2016, Rhode Island led the United States in new distributed wind capacity additions. In contrast, in 2014 and 2015, Rhode Island had no distributed wind projects. Wind Energy Development LLC installed nine new distributed wind turbines in Rhode Island in 2016 using three different contractual approaches.[13] Of these nine turbines, five utilized virtual net-metering arrangements, two employed the state's Renewable Energy Growth tariff program, and two utilized distributed generation power purchase agreement (PPA) contracts.

Rhode Island's net-metering rules were updated in June 2016 to allow for virtual net metering, whereby a facility can use an eligible net metered resource, even if it is not physically located in the immediate vicinity of the facility, and net-metering credits are allocated to the virtual net-metering customer's account. In Rhode Island, virtual net metered systems can be owned by one of the participating customers or financed by a third party and implemented through a PPA or lease arrangement (DSIRE 2017).

Rhode Island's Renewable Energy Growth Program, created through an act of the state legislature in 2014 (Act H 8828) and fully implemented in 2015, was designed to promote the installation of grid-connected renewable energy (DSIRE 2016). The program enables customers to sell their generation under long-term tariffs at fixed prices through competitive bidding to achieve specific MW targets set by the state; annual targets for wind are 9 MW.

The 8 MW Future Generation Wind Project in Plymouth is a unique multi-entity partnership that takes advantage of virtual net metering, renewable energy certificate (REC) revenue, and municipal aggregation policies. It is a remote net metered project owned by ConEdison, with nine off-takers for the power including cities, towns, and school districts. ConEdison sells the RECs from the project separately and some of the RECs are being used by municipalities for their green municipal aggregation programs (Mass Energy 2016). In Massachusetts, green municipal aggregation allows a community to acquire RECs to increase the renewable energy content of its electricity supply above what is required by the state RPS (Mass Energy 2017).

Similar to virtual net metering, the 13 MW South Fork Wind Farm in Minnesota is providing dedicated power to Muscatine Power and Water, a utility located just south of the state border

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[11] Excluding repaid loans, the federal investment tax credit, and federal depreciation.

[12] Incentive funding and commissioning of distributed wind projects often do not overlap. For example, although U.S. Department of Agriculture's (USDA's) Rural Energy for America Program (REAP) grants are recorded for this report in the year they are awarded, they are paid after the project is commissioned. Conversely, the U.S. Department of Treasury 1603 program grants are recorded for this report in the year they are paid, which is also the year they are reported (Treasury 2017). To qualify for 1603 payments, wind power projects must have been under construction or placed in service by the end of 2011 and must have applied for a grant before October 1, 2012. Some payments are still being made, as noted in Figure 8, because 1603 payments are made after the project is placed in service, not prior to, or during, construction. Combined value also includes funding for ancillary equipment for USDA High Energy Cost Grant (HECG) awardees in Alaska.

[13] One additional turbine was repowered in 2016 by Wind Energy Development LLC as well.

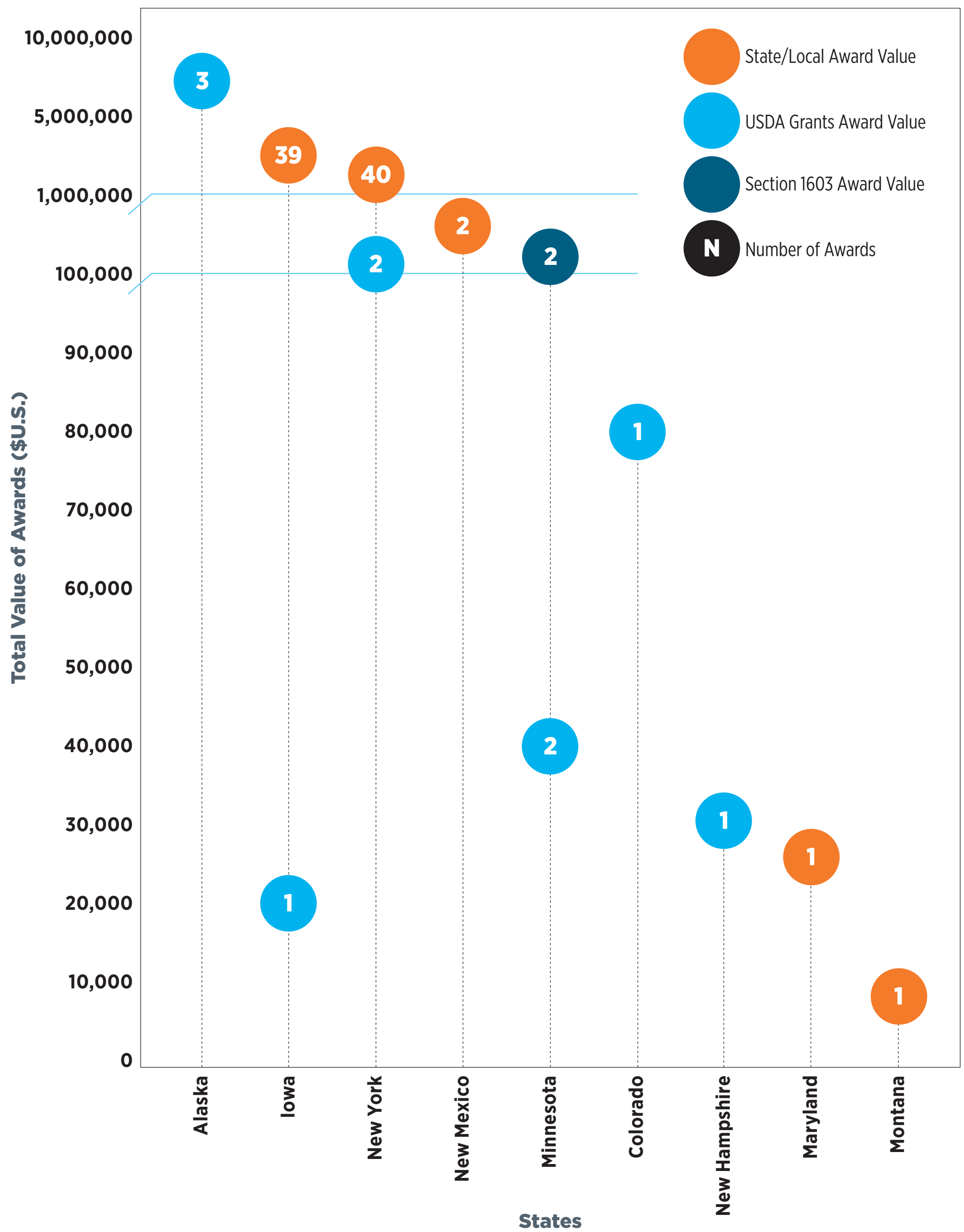

Figure 8. 2016 U.S. distributed wind incentive awards

in Iowa. The wind farm and the utility are both located within the same Midcontinent Independent System Operator Local Resource Zone (MPW 2017).

4.4 Renewable Portfolio Standards

Several states took action to affirm and increase renewable energy goals as well as net metering and distributed energy provisions in 2016.

At the end of 2016, Illinois passed legislation, the Illinois Future Energy Jobs Bill, that adjusts some aspects of the state's RPS, supports local nuclear power plants, and funds renewable energy and energy efficiency programs with over $200 million per year. The bill aims to shift utilities away from purchasing RECs from out-of-state projects to providing incentives for in-state renewable energy projects. The bill also encourages the state to deploy cost-effective distributed energy resource technologies and devices and to facilitate renewable energy procurement and training programs in the state (Illinois 2016).

The 2017 Clean Energy Jobs Act (S.B.921/H.B.1106) increased Maryland's RPS from 20% by 2022 to 25% by 2020. To meet this new goal, approximately 1.3 GW of new clean energy in the state will be needed (Bebon 2017). In addition to this RPS change, the Maryland Energy Administration (MEA) has increased its funding for renewable energy and climate change issues and has proposed funding a Green Bank within the Maryland Clean Energy Center (MEA 2016). Furthermore, Governor Larry Hogan has proposed plans to fund a green jobs training program and to support the creation of a Green Energy Institute to foster investment and commercialization of clean energy within the state (Lillian 2017).

In addition to policies described previously, Rhode Island state legislators approved an increase of Rhode Island's Renewable Energy Standard from 14.5% by 2019 to 38.5% by 2035 (Rhode Island 2016). Concurrently, the state's governor announced a commitment to increase the state's renewable energy resources to 1 GW by the end of 2020 (Rhode Island 2017).

With the passage of Senate Bill 0437 in December 2016, Michigan increased its renewable energy portfolio standard from 10% to 15% percent by 2022, clarified retail net-metering rules, and directed state regulators to establish a tariff process for distributed generation resources (Walton 2016).

4.5 Federal Tax-Based Incentives

The federal Business Energy ITC (26 U.S.C. § 48) and the Residential Renewable Energy Tax Credit (26 U.S.C. § 25D) both provide a 30% credit against the capital costs of eligible renewable energy projects. Small wind's eligibility for the Residential Renewable Energy Tax Credit expired December 31, 2016.

Information on how many small wind projects have claimed the federal Business Energy ITC and the Residential Energy Tax Credit is not public record, so PNNL estimates that 1.5 MW of the 2016 small wind projects in PNNL's project dataset were eligible for the 30% federal tax credit, representing a value of roughly $2.66 million based on average small wind installed project costs.[14]

The federal renewable electricity production tax credit (PTC) (26 USC § 45) is an inflation-adjusted per-kWh tax credit for electricity generated by qualified energy resources and sold by the taxpayer to an unrelated person during the taxable year. Since the adoption of the American Recovery and Reinvestment Act of 2009, projects eligible to receive the PTC have been permitted to opt out of the PTC and instead receive the Business Energy ITC (26 U.S.C. § 48). A wind project qualifies for a phased-down value of the PTC or ITC if it begins construction[15] by the end of 2019 because it produces electricity from wind, a qualified energy resource listed in the Internal Revenue Code. The PTC requirement of electricity sales to an unrelated third party is not a requirement of the ITC. Neither the PTC nor the Business Energy ITC can be claimed for a residential wind project, but small wind projects for taxable businesses are eligible to receive the Business Energy ITC directly or by opting out of the PTC first. After 2019, the PTC and Business Energy ITC will no longer be available for wind projects.

Industry observers expected many large wind projects, whether for distributed generation purposes or otherwise, to have begun construction in 2016 to be eligible for the full PTC or the 30% Business Energy ITC. These expectations were met, with AWEA reporting that 10,432 MW were under construction at the end of the 2016, up from 9,400 MW under construction at the end of 2015. In addition, 67 GW of new proposed wind capacity was added to interconnection queues in 2016, the largest since 2009 (AWEA 2017). However, for small wind projects structured to take the Business Energy ITC in lieu of the PTC, this requirement to begin construction by 2016 to get the full credit is less beneficial because a project entailing one small wind turbine takes months, not years, to develop and install.

Depreciation is another federal tax-based incentive for wind projects. Depreciation allows tax-paying entities to recover investments through depreciation deductions that offset taxable income. Bonus depreciation is allowed in the Modified Accelerated Cost-Recovery System (MACRS) depreciation schedule through December 31, 2019 with a phase-down schedule similar to the ITC/PTC. The bonus depreciation provision accelerates the claiming of depreciation for renewable energy projects, which would otherwise use the five-year MACRS depreciation schedule, enabling additional tax savings to be claimed more quickly.

4.6 USDA REAP

The USDA provides agricultural producers and rural small businesses grant funding as well as loan financing to purchase or install renewable energy systems or make energy efficiency improvements. Through REAP, the USDA issues loan guarantees for up to 75% of the project's cost, or a maximum of $25 million for renewable energy projects. Grants are issued for up to 25% of the project's cost, or a maximum of $500,000 for renewable energy projects. A combination of loans and grants can cover up to 75% of total eligible project costs.

In 2014, Congress passed the Agricultural Act (Public Law 113-79, also known as the "Farm Bill"), which included new and sustained funding for REAP grants and loan guarantees (USDA 2014). The Farm Bill made REAP the largest of its programs, with mandatory funding of $50 million per year through 2018.[16]

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[14] This estimated amount is not included in the $12.8 million total funding amount presented in Section 4.1.

[15] The IRS issued guidance in Notice 2016-31 as to what qualifies as "beginning of construction" (IRS 2016; Milder 2016).

[16] The Distributed Wind Energy Association advocates for retaining and enhancing REAP, along with reinstating the Residential Renewable Energy Tax Credit for small wind.

Table 2. USDA REAP Wind Awards, 2012–2016

	2012	2013	2014	2015	2016
Grant Awards	57	25	15	24	7
Grant Funding ($)	2,554,043	1,193,984	405,442	1,395,748	308,134
Loan Guarantees ($)	15,357,837	4,207,205	1,295,818	5,207,360	-

In 2016, USDA REAP funded seven wind projects with $308,000 in grants, supporting projects costing just over $2 million that are expected to generate 980 MWh of energy annually. This reflects a significant decrease from 2015 levels, when USDA provided $1.4 million in grants for 24 wind projects that cost $6.67 million and were expected to generate 8.7 GWh of energy annually. Although loan guarantees are easy to process by USDA, no loan applications for wind were received in 2016 and thus no loan guarantees for wind were provided.

With 15 applications, REAP funding was awarded to 47% of wind project applications in 2016, compared to 83% of 29 applications in 2015. Wind projects represented 0.6% of all 2016 REAP grant awards (0.9% of REAP funding), energy efficiency projects represented 37% of grant awards (25% of funding), and solar projects represented 58% of awards (56% of funding). In 2015, wind projects were 1.2% of all 2015 REAP awards (and received 1.7% of REAP funding), energy efficiency projects were 36% of awards (24% of funding), and solar photovoltaic (PV) projects were 51% of awards (54% of funding). Other awards include biomass, geothermal, and hydroelectric projects.

Table 2 summarizes the number of grants, grant funding, and loan guarantee funding for wind awards from 2012 through 2016. As Table 2 shows, funding levels have dramatically swung from 2012 and 2017, with 2012 and 2015 reflecting abundant resources, coinciding with the $255 million in mandatory REAP funding from the 2008 Farm Bill and the 2014 reauthorization, respectively.

Since 2003, the total REAP grant funding for wind projects made available has exceeded $71 million, with Iowa ($23.3 million), Minnesota ($21.2 million), Illinois ($4.1 million), Ohio ($2.9 million), and Oregon ($2.8 million) being the top five states in terms of total funding received. The top five states in terms of number of projects awarded are Iowa (264), Minnesota (170), New York (48), Wisconsin (45), and Alaska (30).

4.7 Market Drivers

The distributed wind market continues to face several challenges. States are helping to drive the market with innovative net-metering policies and increases in RPS requirements. Federal agencies, utilities, small wind manufacturers, and industry players are also pushing the market to grow with new programs, business models, and certified turbine models.

Small wind manufacturers and installers report that current challenges include the higher cost of small wind relative to solar PV, the expiration of the federal Residential Renewable Energy Tax Credit for small wind, and the general downward trend in state incentive funding levels and programs.

Without the federal tax credit, some small wind manufacturers will focus on non-taxed institutional and government customers in the coming years. Agricultural customers continue to be an important market as well. Farms structured as businesses are eligible for the Business Energy ITC and farmers value the reliable energy production and small footprint of distributed wind.

4.8 Innovative Programs

The DOE Competitiveness Improvement Project (CIP) awards cost-shared grants via a competitive process to manufacturers of small and medium wind turbines. The goals are to support the reduction of hardware costs, to make wind energy cost competitive with other distributed generation technology, and to increase the number of wind turbine designs certified to national testing standards. Grants fund efforts to increase performance, develop advanced manufacturing processes, or conduct certification of system performance. As of the end of 2016, through four rounds of annual solicitations, DOE has awarded $3.6 million to 16 projects with nine different manufacturers, leveraging an additional $2 million in awardee cost-share.

Xcel Energy recently awarded a $1 million Renewable Development Fund Grant award to Bergey WindPower for the development of 50 planned small wind installations in seven Minnesota counties.[16] As of 2016, one Bergey wind turbine has been installed with this program. The goal of this program is to increase the market penetration of small wind turbines in Minnesota by clustering turbines together, a practice which according to Bergey WindPower has accelerated the market in California and New York (NSPC 2016).

4.9 Business Models

Lease arrangements and other third-party ownership models allow customers to host a wind turbine installed and owned by

[17] Xcel's Renewable Development Fund Grant program was created in 1999 as an outcome of legislation concerning spent nuclear fuel at Xcel Energy's Prairie Island Nuclear Plant and has been awarding grants since 2001 (DOE 2017a).

One Energy Enterprises LLC installed and operates a behind the meter Goldwind 1.5 MW wind turbine that powers a Marathon Petroleum Company pump station in Ohio.
Photo credit: Hank Doster / One Energy Enterprises, LLC

a third party on the customers' property. Customers then make monthly payments in exchange for the installation, operation, and maintenance of the wind turbine, and the energy produced on-site displaces their electricity consumption from the utility and thus lowers their utility bills.

The lease can include guaranteed performance, warranties, maintenance, and insurance—thereby transferring some of the key economic and risk barriers of distributed wind from the customer to the lessor. Barriers include resource uncertainty, site-assessment costs, performance uncertainty, operational maintenance and reliability risks, and the high initial cost of installations.

In January 2016, United Wind, a distributed wind leasing company, announced that it had secured $200 million in project equity capital from Forum Equity Partners to expand its lease program (United Wind 2016). Further, in January 2017, United Wind announced that it had purchased 100 Excel 10 Bergey WindPower wind turbines, the largest order ever—by number of units—for either company (United Wind 2017). United Wind continues to primarily operate in New York, but has expanded to Colorado and Kansas.

Other companies—notably One Energy Enterprises LLC—build, own, and operate behind-the-meter wind projects and sell the power to customers through PPAs. In December 2016, One Energy Enterprises LLC secured $80 million in financing from Prudential Capital Group, signaling institutional capital acceptance of One Energy Enterprises' approach to providing distributed wind to industrial and commercial customers in Ohio (Cision 2017). Ohio's net-metering policy has no system capacity limit, so One Energy Enterprises' customers can have larger wind projects that displace more of their retail rate electricity with guaranteed PPA rates.

4.10 Certified Turbines

Three new small wind turbine models were certified in 2016. As of January 2015, small wind turbines must meet either the AWEA Small Wind Turbine Performance and Safety Standard 9.1-2009[18] or the International Electrotechnical Commission (IEC) 61400-1, 61400-12, and 61400-11 standards to be eligible to receive the Business Energy ITC (IRS 2015).[19] Certifying a turbine model to a standard is the industry approach to proving a turbine model meets the required performance and quality standards. Certification requirements are becoming increasingly common across the globe[20] (e.g., Japan), so small wind manufacturers are pursing the certification process to qualify for FITs and other incentives in export markets. Certification is also consistent with industry and DOE goals to promote the use of proven technology; raise its competitiveness; and increase consumer, government agency, and financial institution confidence and interest in distributed wind.

Table 3 lists the small[21] wind turbines certified as of July 2017 by the Small Wind Certification Council, Intertek, or SGS, all of which are accredited certification bodies.

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[18] 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 will likely be replaced by ANSI/AWEA SWT-1 in the future.

[19] This certification requirement does not apply to qualified wind projects that elect to opt out of the PTC into the Business Energy ITC.

[20] The International Energy Agency promotes international harmonization for certification requirements to minimize testing requirements and maximize reciprocity opportunities.

[21] International and domestic certification standards define wind turbines based on their rotor swept area, rather than their nominal capacity. For certification purposes, small wind turbines are those having rotor swept areas up to 200 m^2 (approximately 50 to 65 kW) and medium wind turbines are those having rotor swept areas greater than 200 m^2. Three medium wind turbine models have published power performance and acoustics certifications to IEC 61400-12-1 (power) and IEC 61400-11 (acoustics).

Table 3. Certified Small Wind Turbines (IREC 2017)

Applicant	Turbine	Date of Certification	Rated Annual Energy[1] @ 5 m/s (kWh)	Rated Sound Level[2] (dB(A))	Certified Power Rating[3] @ 11 m/s (kW)
Bergey WindPower	Excel 10[4]	11/16/2011	13,800	42.9	8.9
Eocycle Technologies, Inc.	EO20[5]	3/21/2017	64,920	44.3	22.5
Eveready Diversified Products	Kestrel e400nb[4]	2/14/2013	3,930	55.6	2.5
Kingspan Environmental	KW6[4]	6/17/2013	8,950	43.1	5.2
Lely Aircon B.V.	LA10[4]	1/13/2017	17,500	41.1	9.6
Lely Aircon B.V.	LA30[4]	1/13/2017	48,800	49.8	27.2
Osiris Technologies	Osiris 10[6]	9/27/2013	23,700	49.4	9.8
Pika Energy	T701[4]	1/25/2016	2,420	38.3	1.5
Sonkyo Energy	Windspot 3.5[6]	10/30/2012	4,820	39.1	3.2
Sumec Hardware & Tools Co. LTD	PWB01-30-48[6]	5/20/2013	2,920	41.1	1.2
Sumec Hardware & Tools Co. LTD	PWA03-44-250[6]	12/26/2012	6,400	40.9	3.2
Sumec Hardware & Tools Co. LTD	PWB02-40-48[6]	5/20/2013	4,660	36.9	1.7
Sumec Hardware & Tools Co. LTD	PWA05-50-280[6]	12/26/2012	9,240	42.0	5.0
Xzeres Wind Corporation	442SR[4]	2/6/2015	16,700	48.5	10.4
Xzeres Wind Corporation	Skystream 3.7[4]	12/19/2011	3,420	41.2	2.1

[1] Estimated annual energy production assuming an annual average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, sea-level air density, and 100% availability. Actual production will vary depending on site conditions.

[2] The sound level that will not be exceeded 95% of the time, assuming an annual average wind speed of 5 m/s, a Rayleigh wind speed distribution, sea-level air density, 100% availability and an observer location 60 m from the rotor center.

[3] 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).

[4] Certified by SWCC

[5] Certified by SGS

[6] Certified by Intertek

5.0 Installed and Operations and Maintenance (O&M) Costs

This section looks at how distributed wind costs can be classified and what those costs are. Cost data in this section were derived from manufacturers, state and federal agencies, project owners and developers, installers, and news reports.

5.1 Understanding Distributed Wind Costs

Project cost data were collected from multiple sources and can be understood and organized in different ways, as described below.

5.2 Distributed Wind Taxonomy

In March 2017, the National Renewable Energy Laboratory (NREL) published the DOE-funded report titled *The Distributed Wind Cost Taxonomy* that describes a classification system, or taxonomy, for distributed wind project costs (Forsyth et al. 2017). The costs included in the taxonomy include wind turbine system equipment costs and balance-of-system costs. The taxonomy provides a framework to support consistency in collecting, sorting, and comparing distributed wind cost data and tracking trends over time (Forsyth et al. 2017). Understanding the details of all costs incurred in developing and commissioning a wind turbine system, including labor, equipment, and materials, is the first step in identifying valuable cost-reduction opportunities (Forsyth et al. 2017).

PNNL and NREL have collected cost data for a number of distributed wind projects using the taxonomy framework. PNNL will present cost benchmarking analysis and identify strategic cost-reduction opportunities in a report to be published in September 2017.

5.3 Turbine System Equipment Costs, Balance of Station Costs, and Barriers

The turbine system equipment, or the hardware components of a distributed wind system, include the rotor assembly (i.e., blades), nacelle assembly (i.e., mainframe and cover, drivetrain, and yaw system), monitoring equipment, electrical system, and tower.

The balance of station costs of a distributed wind system include customer acquisition and qualification; installation, foundation, and electrical labor, materials, and equipment; transportation; taxes; zoning, permitting, inspection, interconnection, and incentive labor and fees; engineering and design (e.g., site assessment, foundation design, and geotechnical report); financing; and overhead and profit. For a successfully installed distributed wind project, these costs can range from minor to significant in value as a portion of the total project cost.

However, some potential projects are never installed because of barriers encountered in the development phase. Therefore, the "cost" of a barrier that causes a project to fail cannot be tracked by the Distributed Wind Taxonomy because the wind system was not installed. For example, one installer who responded to the data request for this report explained that a conditional use permit is required in his county for a distributed wind system. The permit costs $2,500 and requires a public hearing. This would be a balance of station cost for a successfully installed project, but the fee is not refundable if the permit is denied, causing the project to not be installed. This permit requirement has proven to be a significant barrier for potential distributed wind system owners in this particular county; many do not even attempt to pursue an installation.

5.4 Small Wind Installed Costs

PNNL asked small wind turbine manufacturers to report the average, or typical, installed cost of each of its turbine models sold in the United States. Figure 9 presents the manufacturer-reported average annual installed costs, not adjusted for inflation, for newly manufactured small wind turbines installed in the United States from 2005 through 2016. Because the wide range of small wind turbine sizes (i.e., <1 to 100 kW) result in a wide range of costs, small wind turbines are examined in smaller groups. For 2012 through 2016, the average costs of small wind are also categorized into three different size ranges: less than 2.5 kW, 2.5 to 10 kW, and 11 to 100 kW.

Small wind turbine installed costs reported by manufacturers were trending downward, driven mainly by the cost of turbines in the 11 to 100 kW size range, but have plateaued in 2016. The overall capacity-weighted average installed cost of 2.4 MW of small wind turbines sold in the United States in 2016 was $5,900/kW. This compares to $5,760/kW from 1.6 MW of sales in 2015, $6,230/kW in 2014 from 2.8 MW of sales, and $6,940/kW in 2013 from 5 MW of sales.

PNNL also asked installers and developers to report the total installed cost of each project they install for the given year. Figure 10 shows the project-specific installation costs reported by installers for 1.26 MW representing 57 wind turbines across 10 states. Note that Figure 10 shows costs before any incentives and includes only those 2016 small wind projects for which cost information was available.

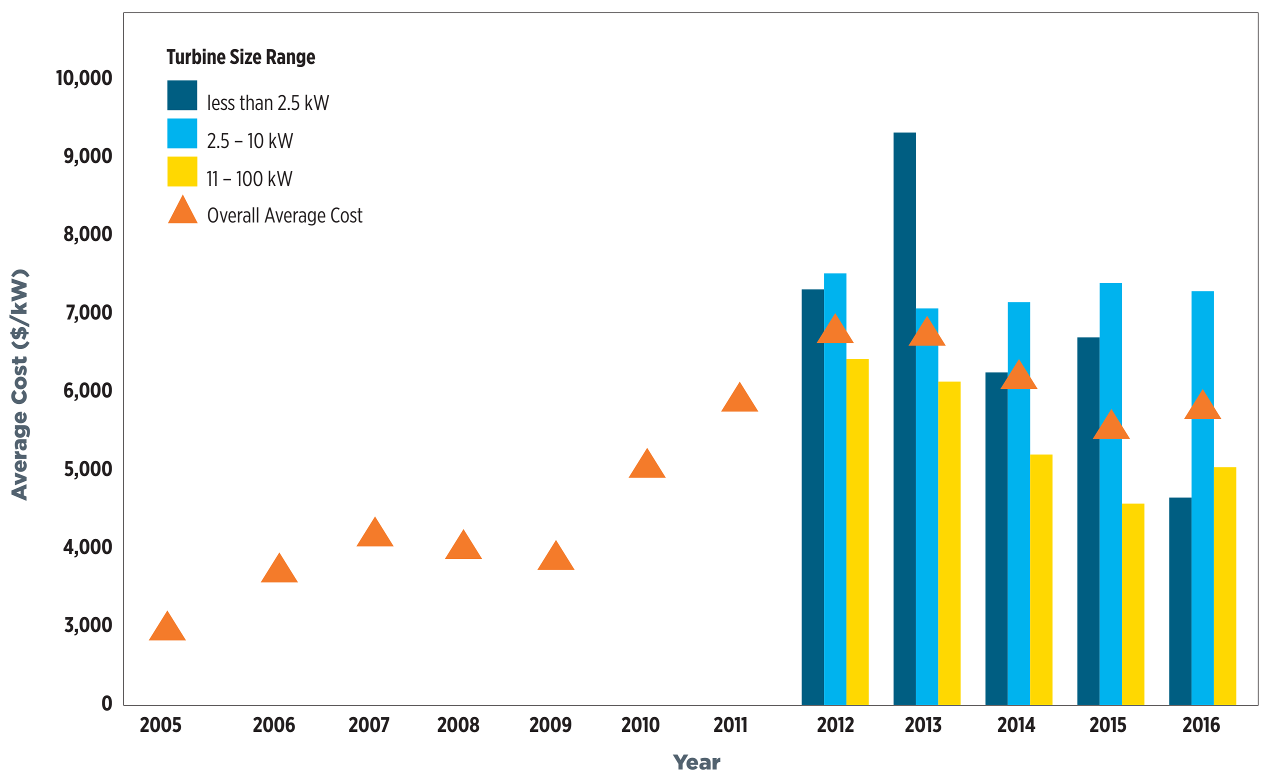

Figure 9. Newly manufactured small wind average installed costs reported by manufacturers

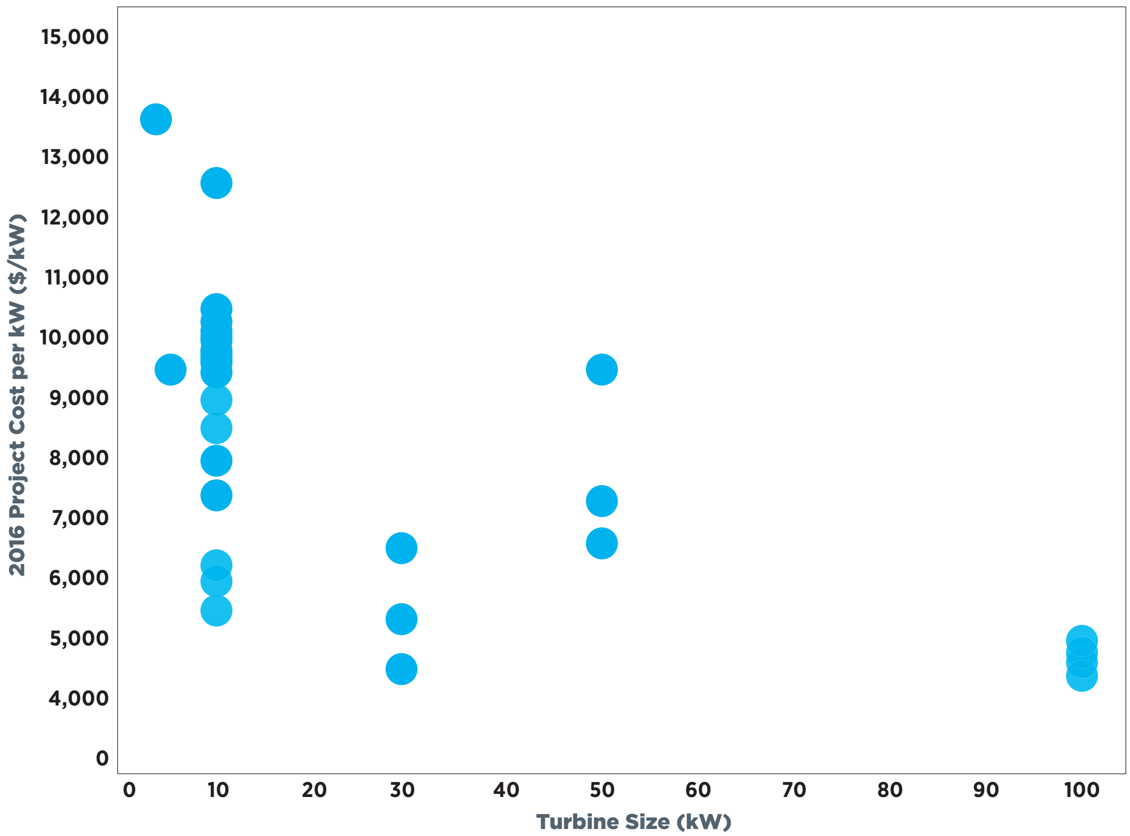

Figure 10. 2016 small wind project installed costs

The capacity-weighted average installed cost of this sample of projects from installers is $7,906/kW, which is higher than the $5,900/kW overall small wind capacity-weighted average as reported by manufacturers. While the manufacturers provide a typical installed cost estimate for each turbine model, the data suggest that actual installed costs are impacted greatly by site-specific issues, such as foundation and construction requirements, local installation labor, permitting requirements, and shipping costs. With the Distributed Wind Taxonomy now established, future analysis of installed costs for this report will rely on the taxonomy to understand the distinctions between turbine system equipment costs, which manufacturers can reliably report without knowledge of project-specific issues, and balance-of-station costs, which installers can report per the taxonomy cost categories.

5.5 Installed Costs for Projects Using Wind Turbines Greater than 100 kW

For turbines greater than 100 kW installed in the United States in 2016, project cost information was available for eight projects representing 11.3 MW and eight turbines in four states and Guam. The capacity-weighted average cost of these projects is $3,470/kW. The availability of cost information for distributed wind projects using turbines greater than 100 kW, and the location of these projects, varies from year to year. As a result, annual average costs vary as well. The average cost for 2015 projects was $3,433/kW from 14.5 MW representing eight turbines in four states. The combined 2013 and 2014 average cost was $2,966/kW from 24 MW and 16 turbines in seven states.

Distributed wind projects using turbines greater than 100 kW tend to have higher costs per kW compared to wind farms. Distributed wind projects often employ a small number of turbines, or even a single wind turbine, and do not benefit from the economies of scale available to larger projects. Also, for the same size turbine, manufacturers may charge more for a single turbine order than for a bulk turbine purchase.

5.6 O&M Costs

Determining O&M costs for distributed wind projects is challenging. The Distributed Wind Cost Taxonomy can also be used to classify and understand O&M costs. This will allow for better understanding of O&M costs once a dataset is established. Without the taxonomy, O&M cost reports vary widely depending on perspective. From the O&M service provider's perspective, O&M costs depend on the provider's proximity to the project site (i.e., travel costs), support from the wind turbine manufacturer (i.e., availability of spare parts), and the complexity of maintenance or repairs. However, manufacturers' estimates of O&M costs may only consider parts and materials costs, not the labor or travel costs of the service provider. O&M service providers supplied estimated O&M costs in response to the data request for this report for distributed wind projects using a range of turbine models. Average O&M costs were derived from these reports, as detailed in Appendix B, to use in the levelized cost of energy (LCOE) calculations reported in Section 7.0.

6.0 Performance

A wind project's capacity factor is one way to measure the project's performance. Capacity factor, expressed as a percentage, 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 nominal capacity.[22]

The capacity factors of distributed wind projects from three datasets—USDA REAP, NYSERDA, and U.S. Energy Information Administration (EIA)—were calculated based on the annual energy generation values reported in the datasets. In addition, PNNL used the datasets to examine the relationship between projected performance and actual performance. These datasets are independent of PNNL's project dataset described in Section 1.3 and Appendix B.

6.1 Capacity Factors

Figure 11 presents the calculated small wind capacity

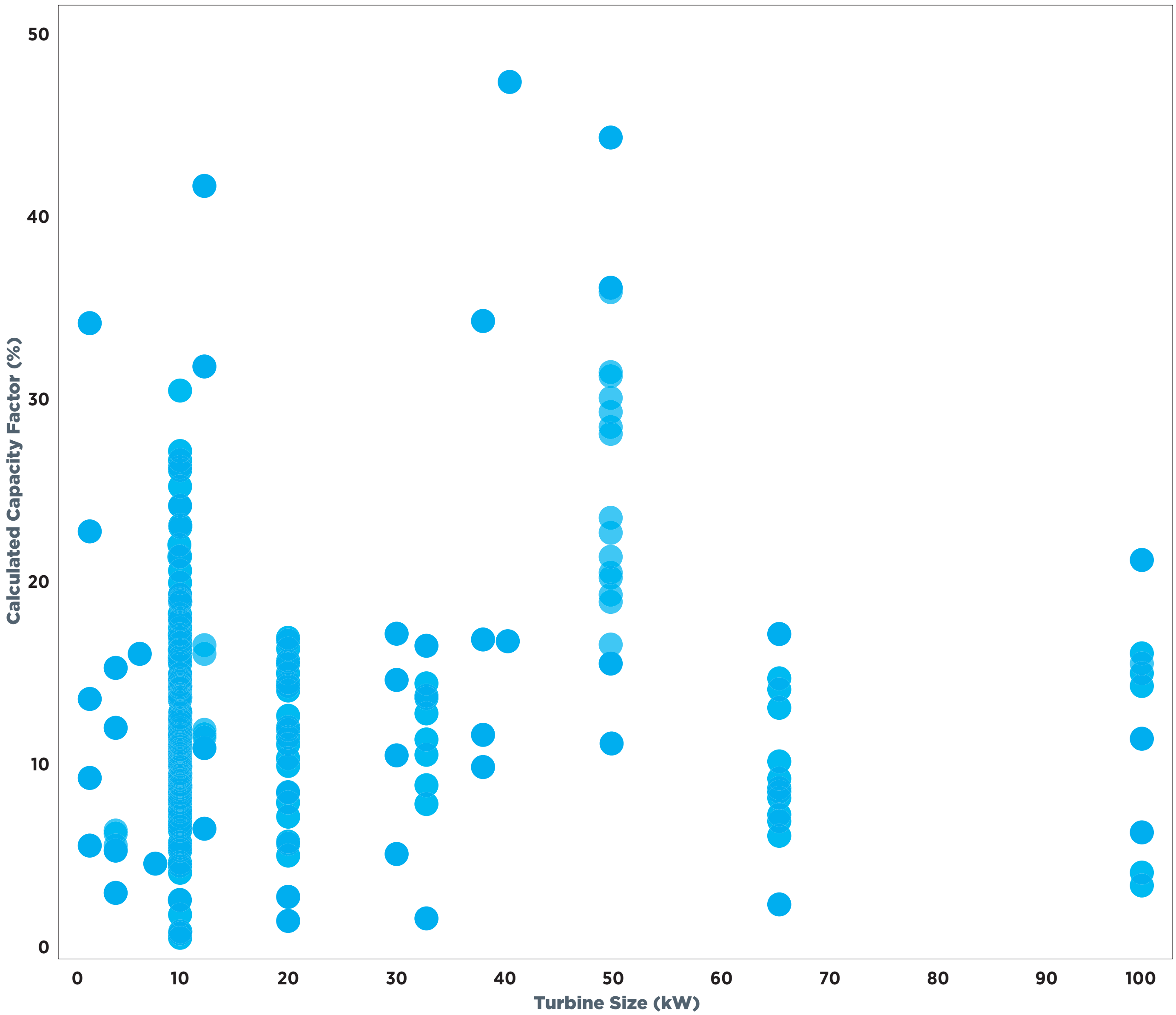

Figure 11. Small wind capacity factors

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[22] The capacity factor calculation in this report uses the turbine's nominal, or nameplate, capacity, not its rated capacity. A turbine's rated capacity is its power output at 11 m/s per AWEA Standard 9.1-2009.

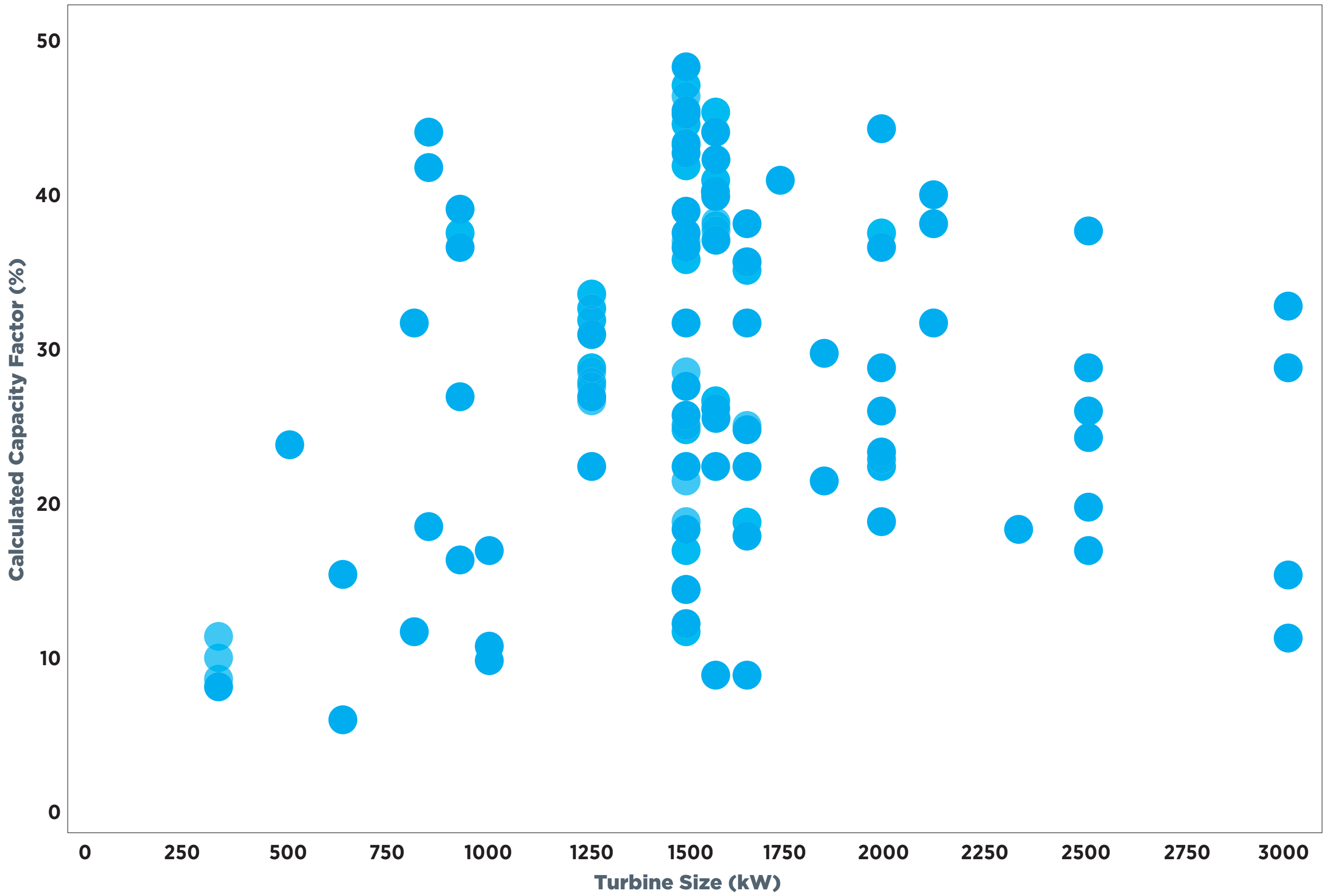

Figure 12. Capacity factors for projects using turbines greater than 100 kW

factors, based on each project's first year of generation, from the combined datasets. Figure 12 presents the calculated 2015 capacity factors for the projects using turbines greater than 100 kW.

The capacity factors shown in Figure 11 and Figure 12 represent a wide variety of projects. The USDA REAP dataset includes 85 small wind projects (2.9 MW), two mid-size turbine projects (1.5 MW), and 14 large turbine projects (21.9 MW) that were awarded grants in 2009 through 2016 in 10 different states. After the grant is awarded, a grant recipient has up to two years to install the project. The 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 150 small wind projects (2.35 MW) and five mid-size turbine projects (1.95 MW) installed in 2008 through 2015 in New York. After installation, rebate recipients are required to submit performance reports at least twice a year for two years. This analysis looks at the first year of generation where the first year is defined as the first 12 months of operation after installation, as opposed to a calendar year.[23]

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 2016). From these records, 104 distributed wind projects across 19 states totaling 436 MW were identified.[24] These projects were installed from 2003 to 2013. The capacity factors for the EIA projects included in Figure 12 are based on the reported 2015 generation amounts because 2015 is the most recent year for which a significant number of EIA-reported projects aligned with PNNL's distributed wind project records.

The large turbine project average capacity factor is 34%. The mid-size turbine project average capacity factor is 22%. The small wind average capacity factor is 15%.

[23] While many projects in these datasets had multiple years of reported performance, for simplicity this analysis looks only at the first year of generation. 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. Future market report analysis may consider other years and inter-annual generation amounts.

[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.

It is not surprising that large turbine projects achieve high capacity factors because large turbine projects, whether for distributed generation purposes or otherwise, require significant investment, are 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. The average 2015 capacity factor for all wind projects using turbines greater than 100 kW built in the United States from 2004 to 2011 was 31.2% (Wiser and Bolinger 2016), comparable to this combined dataset's average and installation time period. The low average for the mid-size turbines may be a result of the small sample size and the wide range of small wind capacity factors reflects the assessment and siting challenges for small wind discussed below.

The capacity factors for the 10 kW turbines range from 1% to 31% and the capacity factors for the 50 kW turbines range from 11% to 44%. These ranges underscore the idea that siting and availability issues influence capacity factors. The same turbine model sited in two different locations can achieve very different capacity factors. In addition, low turbine availability, as a result of a turbine not operating for extended periods of time, can also lower the turbine's overall annual capacity factor.

6.2 Actual Project Performance

Figure 13 compares the projected performance and actual performance for the USDA REAP and NYSERDA projects broken out by turbine size class: small certified turbines, small non-certified turbines, mid-size turbines, and large turbines. Each line in each histogram represents an individual project within the turbine size class.

Figure 13 illustrates how wind resource assessment, siting, and availability issues can impact performance predictions. Actual performance can be either much higher or much lower than projected performance. The inability to consistently and accurately predict performance can negatively impact consumer confidence in distributed wind and access to financing.

The project-specific details that drive each project's actual energy generation amounts were not available for review for this report, but the amount of annual energy production that can be achieved by a distributed wind project is driven by many variables, primarily the project's available wind resource, siting (e.g., tower height, local obstructions, and other micro-siting issues), and availability (e.g., downtime for expected or unexpected maintenance).

The REAP and NYSERDA incentive programs require applicants to include a projected annual energy generation value in their applications, and this value is a factor in how REAP applications are scored and how the incentive value paid by NYSERDA is calculated.

In these datasets, the projects using large turbines over perform compared to the projects' projected performance at the time of incentive application. As mentioned, large turbine projects require significant investment, are likely sited to achieve optimal energy generation, and also typically conduct a formal wind resource assessment with a meteorological tower.

In contrast, the projects using small and mid-size turbines in these datasets tend to underperform compared to the projects' projected performance. The limited sample size for the mid-size turbine class may account for some of the discrepancy between projected and actual performance for this turbine size class. The certified small wind turbines do exhibit a higher average of percent of projected production (89%) than the non-certified small wind turbines (64%), but this difference cannot be attributed solely to the turbine technology. Actual performance, compared to predicted performance, is also driven by wind resource assessment methodologies, micro-siting issues, and turbine availability.

It is not cost effective for small wind projects to use meteorological towers. Therefore, small wind resource assessments rely on online tools, wind resource maps, and simple models to estimate a site's wind speed that is then used to estimate annual energy production. According to a survey of current industry distributed wind resource assessment practices, the high cost and long time frames of measurement-based wind resource assessments mean small wind installers and developers often use rule-of-thumb methods and simplified model-based approaches that lead to a high level of uncertainty in energy estimates (Fields et al. 2016). To increase consumer confidence in distributed wind performance, and improve the overall LCOE of the distributed wind fleet by decreasing the number of underperforming or short-lived turbines, the industry needs to focus on creating reliable, well documented, and independently verified methodologies for wind resource assessments (Fields et al. 2016).

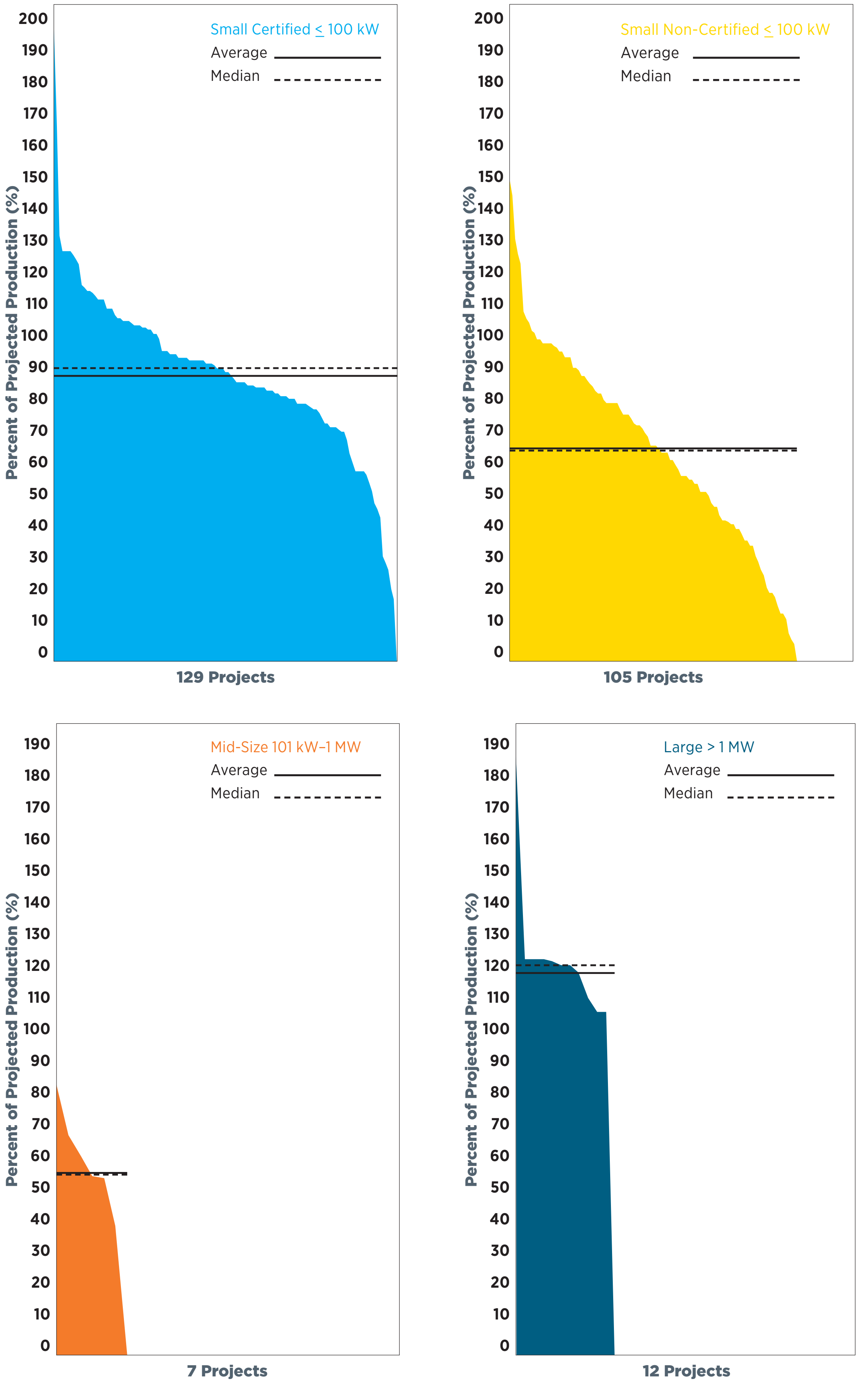

Figure 13. Actual performance for USDA REAP and NYSERDA projects

7.0 Levelized Cost of Energy

The installed cost of the wind turbine and its performance, or capacity factor, are drivers of a project's LCOE.

LCOE is a function of a project's costs (installed and O&M) divided by its annual energy production and is therefore expressed in $/kWh or ¢/kWh. Appendix B describes NREL's recommended method and assumptions used to calculate distributed wind LCOE (NREL 2013).

Using the three datasets from USDA REAP, NYSERDA, and EIA again, LCOE values were calculated.

7.1 Levelized Costs of Energy by Turbine Size Class

Figure 14 presents the calculated small wind LCOEs from the NYSERDA and USDA REAP datasets. Figure 15 presents the calculated LCOEs for the projects using turbines greater than 100 kW from the three combined datasets.

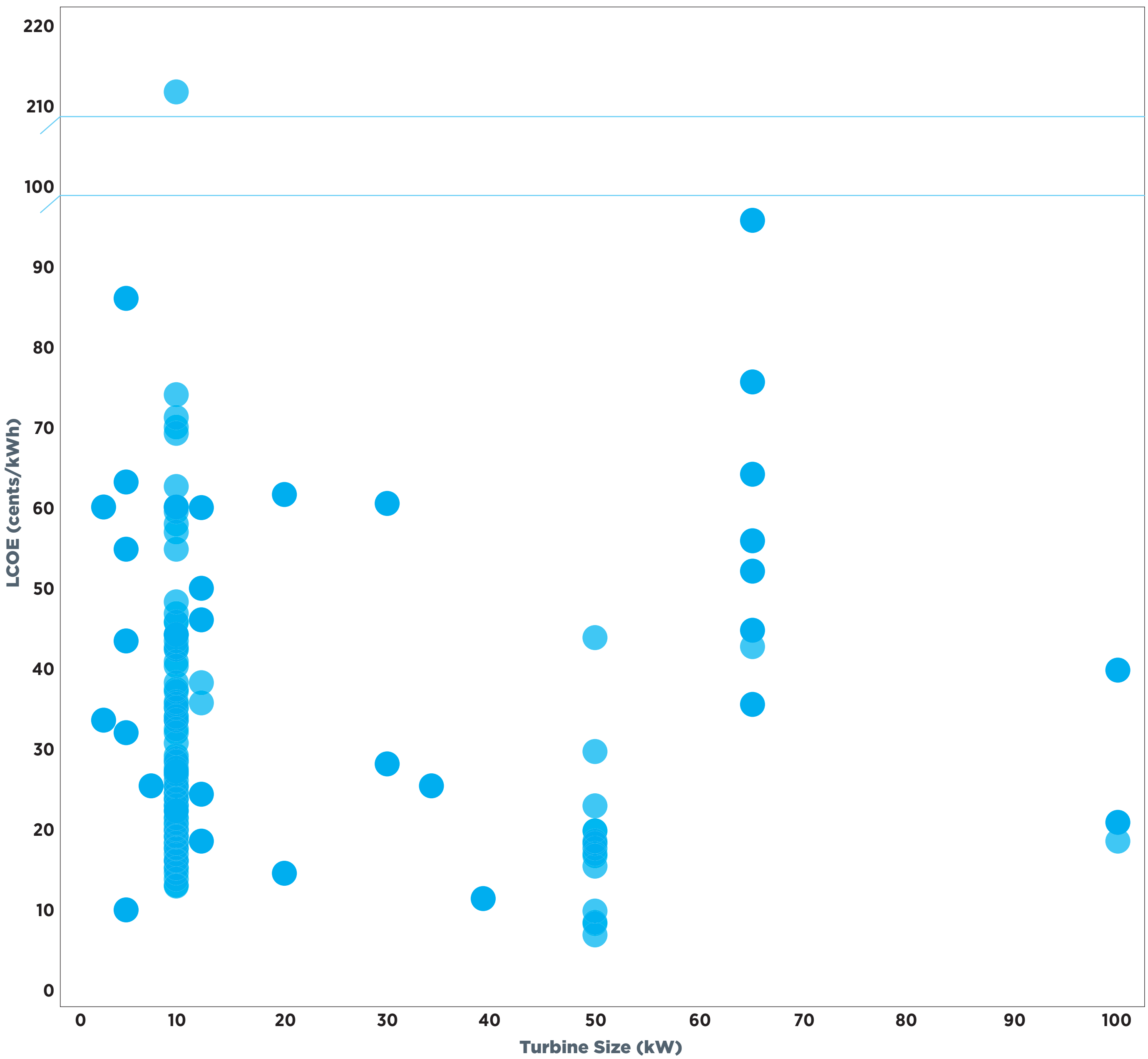

Figure 14. Small wind levelized costs of energy

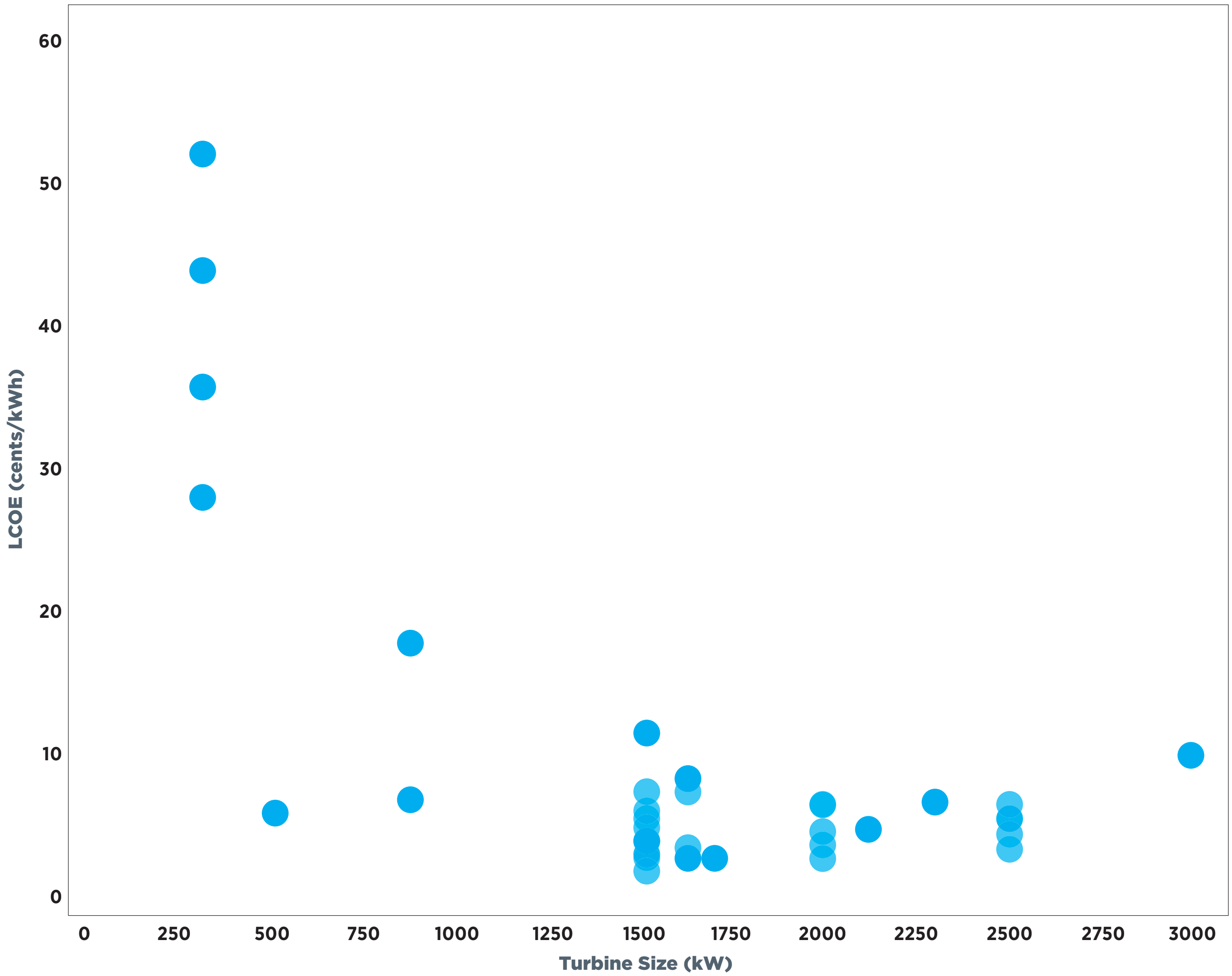

Figure 15. Levelized costs of energy for projects using turbines greater than 100 kW

The large turbine project average LCOE is 5¢/kWh. The mid-size turbine project average LCOE is 8¢/kWh. The small wind average LCOE is 24¢/kWh.

The LCOE calculations are based on the annual energy generation, total cost, and incentive values reported for the projects in the REAP and NYSERDA datasets, and PNNL project records for total cost and incentive values that correlate to the annual energy generation amounts from the EIA dataset. The O&M costs are estimates from service providers as discussed in Section 5.3.[25] The LCOE analysis is limited to projects for which all of this information is available. This results in a limited mid-size turbine project sample size with a wide range of calculated LCOEs. As a result, the mid-size turbine capacity-weighted average LCOE value is skewed by the better performing projects that use multiple mid-size turbines.

The installed capital cost for each project was reduced by the NYSERDA, REAP, or Section 1603 incentive award for the LCOE calculation.[26] A rebate or grant reduces the upfront cost for the wind turbine owner significantly and thus reduces the LCOE to the owner as well.

NYSERDA rebates are up to 50% of the project cost (via an incremental performance-based incentive). USDA REAP grants are up to 25% of eligible project costs, or a maximum of $500,000. Section 1603 cash grants are valued at up to 30% of eligible project costs.

[25] All costs in the LCOE calculations are in 2016 dollars. The NYSERDA and USDA REAP generation amounts are each project's Year 1 value, as described in Section 6.1. The EIA generation amounts are the 2015 reported values.

[26] A project may have received another incentive (e.g., from a utility), but only the incentive applicable to the respective dataset were applied to this calculation for simplicity.

The NYSERDA and USDA REAP incentives reduced the small wind LCOEs by an average of 29%. The Section 1603, NYSERDA, and USDA REAP incentives reduced the mid-size and large turbine projects by an average of 17%.

Figure 14 and Figure 15 shows the scatter of LCOEs achieved by distributed wind projects. Some of these LCOEs are cost competitive with retail electric rates. Behind-the-meter distributed wind projects displace retail electric rates. According to the EIA, average residential retail electric rates in the continental United States range from 9.3¢ to 20¢/kWh, which small wind turbines are most likely to displace, and average commercial rates range from 7.5¢ to 15¢/kWh, which mid-size and large turbines could displace (EIA 2017). 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 the calculated LCOEs and the capacity factors from the datasets is shown in Figure 16. 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).

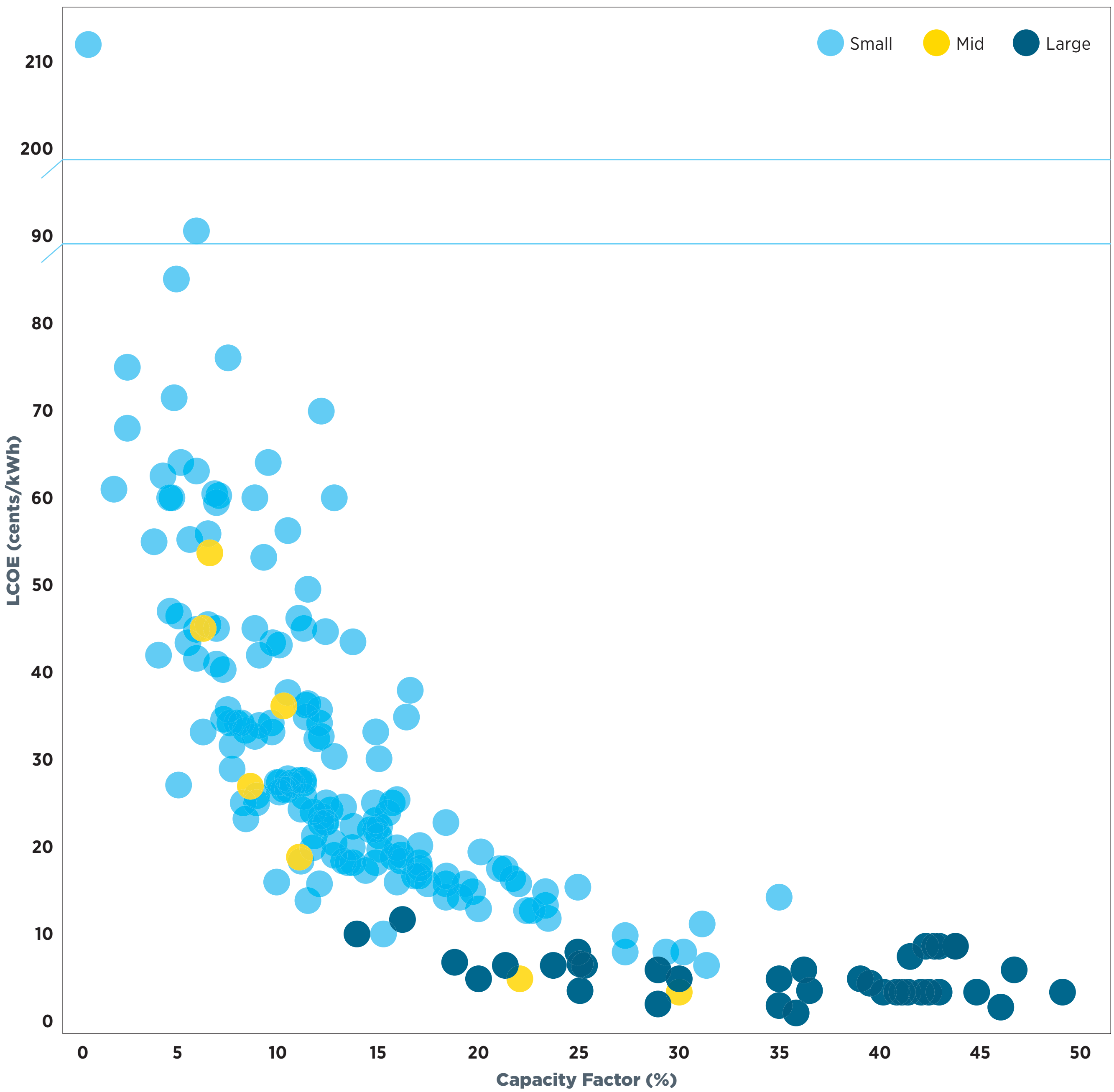

Figure 16. Levelized costs of energy and capacity factors

8.0 Distributed Wind Markets

Distributed wind projects range from a small turbine at an off-grid home to a large-scale turbine at a manufacturing facility. This section of the report looks at some of the details for the 2016 distributed wind sales and installations.

8.1 Customer Types

This report considers six main customer types for distributed wind: 1) residential, 2) agricultural, 3) industrial, 4) commercial, 5) government, and 6) institutional. Residential applications include remote cabins, private boats, rural homesteads, suburban homes, and multi-family dwellings. Agricultural applications include all types of farms, ranches, and farming operations. Industrial applications are facilities that manufacture goods or perform engineering processes (e.g., food processing plants, appliance manufacturing plants, and oil and gas operations). Examples of commercial applications include offices, car dealerships, retail spaces, restaurants, and telecommunications sites. Government applications are projects for non-taxed entities such as cities, municipal facilities (e.g., water treatment plants), and military sites. Institutional applications are for entities that may also be non-taxed and mainly consist of schools, universities, churches, and electric co-operatives and utilities.

Figure 17 shows the breakdown of customer types by number of projects[27] and by capacity for 2016. The figure illustrates how a small percentage of projects using large-scale turbines in institutional and government applications can account for much more capacity than many projects using small wind turbines in agricultural and residential applications.

8.2 On-Site Use and Local Loads

In simple terms, a wind turbine or project is considered to provide distributed energy if it serves an on-site load (i.e., behind the meter, remote net metered, or off-grid) or if it is connected to the local distribution grid to serve local loads (i.e., the generated energy is not sent past the local substation).

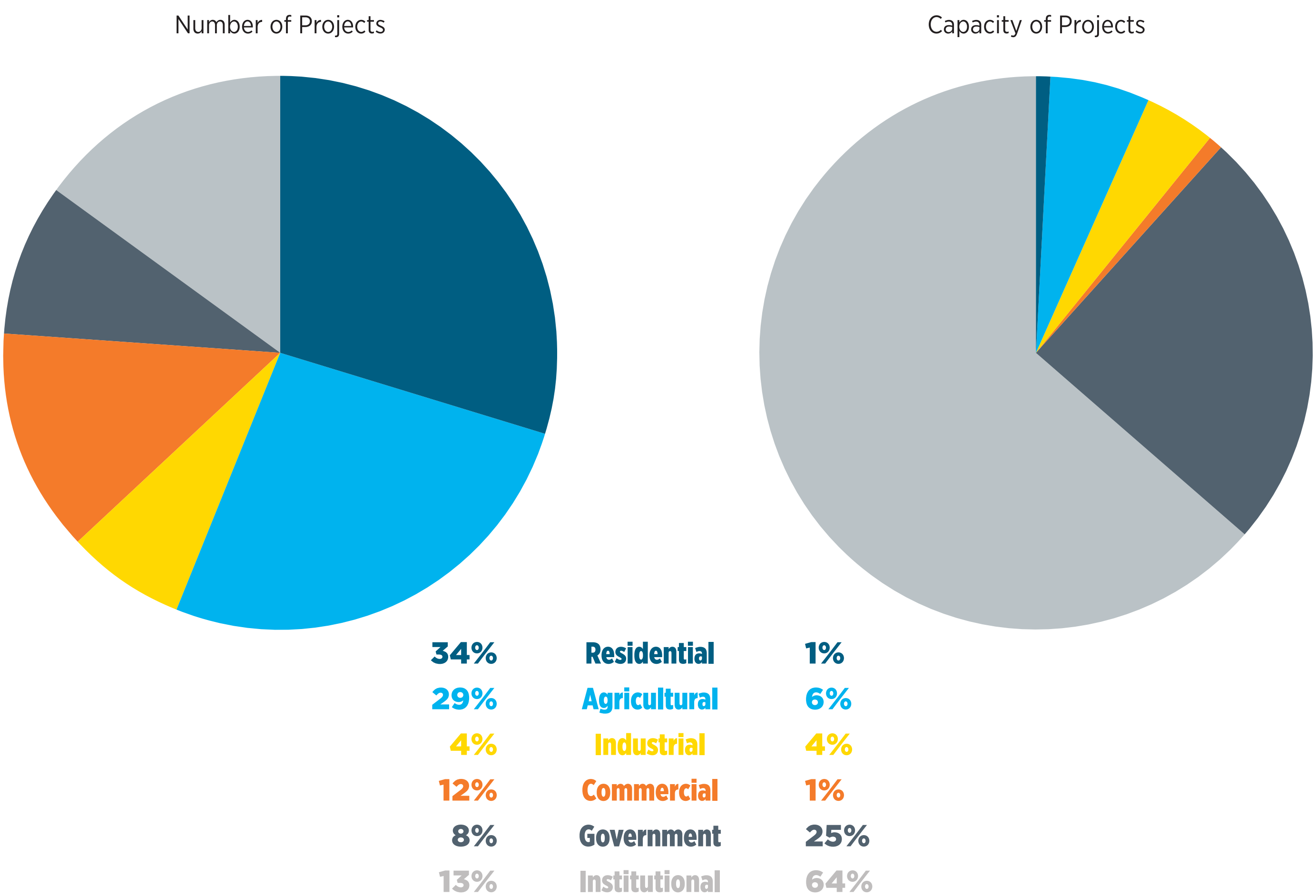

Figure 17. 2016 distributed wind customer types by capacity and by project

[27] Small, off-grid turbine units are unable to be tracked at the project level, so are not accounted for in Figure 17, as noted in Section 1.3.

On a capacity basis, 40% of the documented 2016 distributed wind capacity, from five projects, was connected to distribution lines serving towns and utility service areas in Alaska, Guam, Iowa, and Rhode Island. The other 60%, from 100 different projects, served on-site loads, either as behind-the-meter (21%), off-grid (1%), micro-grid (less than 1%), or remote net-meter (37%) applications across 24 states.

8.3 Off-Grid and Grid-Tied

Off-grid small wind turbine models continue to account for the bulk of wind turbine units deployed in U.S. distributed wind applications. An estimated 95% of turbine units in 2016 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, and military sites. However, grid-tied wind turbines accounted for nearly 99% of the annual distributed wind capacity (in terms of MW).

8.4 Types of Wind Turbines

The overall number of wind turbine manufacturers supplying turbines for distributed wind projects has contracted significantly since 2012. In 2016, reported U.S. distributed wind projects encompassed 29 different wind turbine models[28]

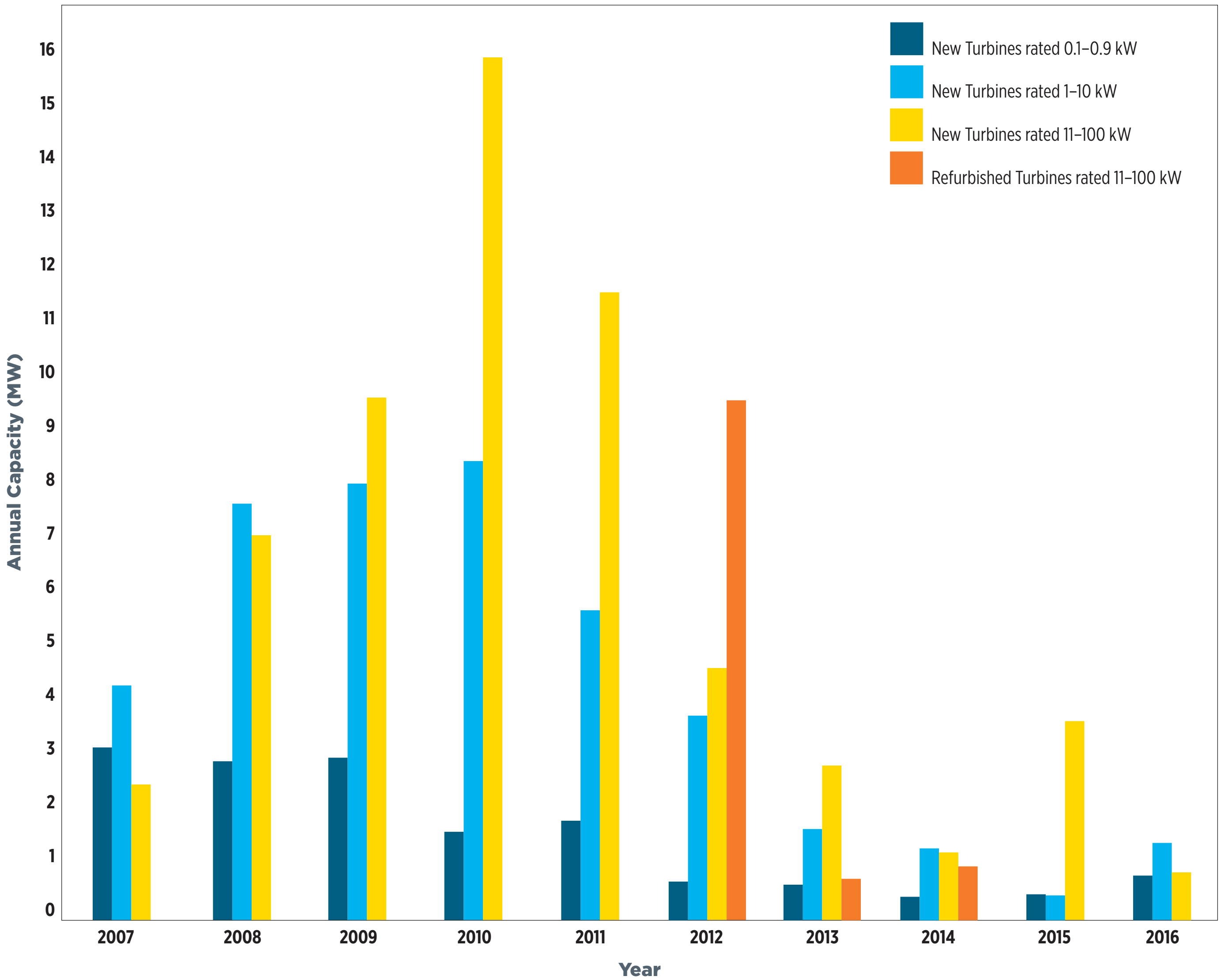

Figure 18. U.S. small wind deployed capacity by turbine size

[28] Turbine models can be newly manufactured, refurbished, or retrofitted. 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 newly manufactured turbine (i.e., nacelle, rotor, and generator) installed on an existing tower. For the purpose of 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 qualify for the federal ITC.

ranging from 160 W to 2.3 MW from 17 manufacturers. This is comparable to 2015 during which there were 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 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.

Of the top 11 models of all 2016 wind turbines deployed in U.S. distributed applications (on a unit basis), eight were from U.S.-based manufacturers.

As discussed previously, some small wind manufacturers do not have consistent sales from year to year. Of the 22 small wind turbine models (reported by 12 manufacturers) deployed in the United States during 2016 reported, eight have nominal capacity ratings less than 1 kW, 12 are rated 1 to 10 kW, and two are rated 11 to 100 kW. In contrast, in 2015, there were four models with nominal capacity ratings less than 1 kW, eight models rated 1 to 10 kW, and five rated 11 to 100 kW. The deployed capacities for all of these turbines are shown in Figure 18.

While there are many small wind vertical-axis wind turbine (VAWT) manufacturers, this report only captures sales from those who responded to the report's annual data request. As a result, consistent with past years, VAWT models represent less than 1% of both U.S. small wind market units and capacity for 2016 per PNNL's project dataset.

8.5 Types of Towers

A wide range of tower designs and heights were sold for small wind turbine projects. In 2016, the most common tower type for the smaller turbines (less than 2.4 kW) primarily used in off-grid applications was the guyed monopole. For the remainder of turbines, the most common tower types, in order of prevalence, were self-supporting lattice, self-supporting monopole, tilt-up monopole, and guyed lattice.

Reported hub heights for documented small wind projects in 2016 ranged from 6 to 44 m, with 42.7 m (140 ft) being the most common. The hub height for the one mid-size turbine installed in 2016 was 55 m. For the turbines greater than 1 MW, five projects used 80 m towers, six projects used 85 m towers, and one project used a 100 m tower.

8.6 Distributed Wind Turbine Units

Wind turbines of all sizes in distributed wind applications account for 65% of the roughly 120,000 total wind turbines deployed in the United States (on a unit basis) since 2003 (Figure 19). In past years, the number of small wind turbines deployed exceeded the number of wind turbines installed in wind farms, resulting in the high small wind cumulative turbine units number. However, a large number of units does not always equate to a large amount of

A 10 kW Xzeres Wind 442SR wind turbine being installed in South Dakota.
Photo credit: Dennis Williams / Willams Power Systems.

capacity. For example, distributed wind accounted for less than 1% of all wind capacity installed in 2016, consistent with prior years. Although distributed wind projects are not defined by project size, 89% of 2016 distributed wind projects were single-turbine projects. For context, wind turbines greater than 100 kW installed in wind farms (i.e., projects that do not meet the definition of distributed wind) are also shown in Figure 19.

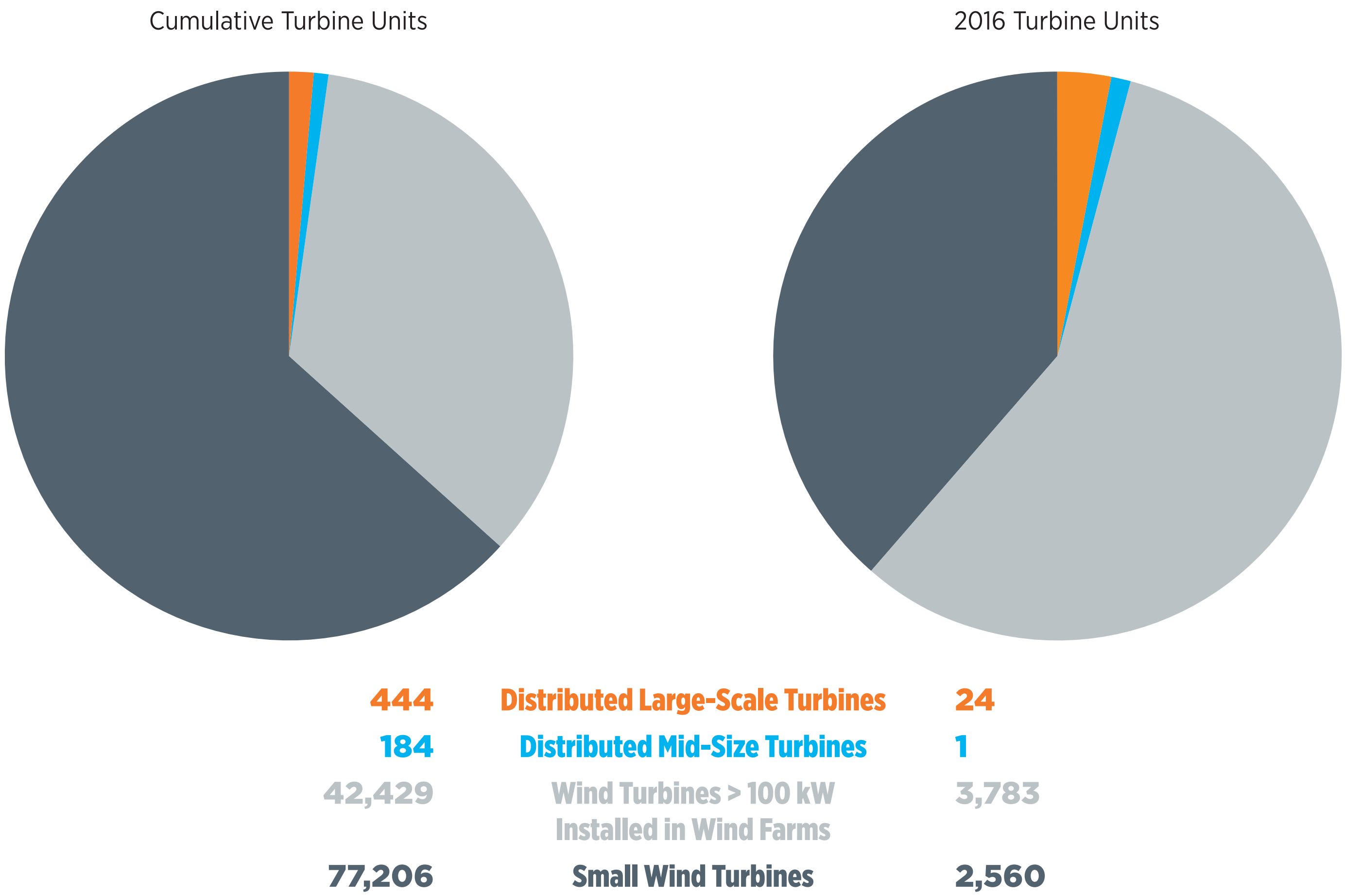

Figure 19. Cumulative (2003–2016) and 2016 wind farm and distributed wind turbine units

9.0 Small Wind Manufacturing

U.S.-based small wind turbine manufacturers in eight different states reported sales in 2016 and rely on U.S. supply chain vendors from at least 23 different states for most to all of their wind turbine components. As a result, small wind manufacturing is represented in at least 27 states, as shown in Figure 20.

Self-reported domestic content levels for 2016 ranged from 80% to 100%. These supply chain vendors provide the mechanical, electrical, tower, and blade components essential to small wind turbines.

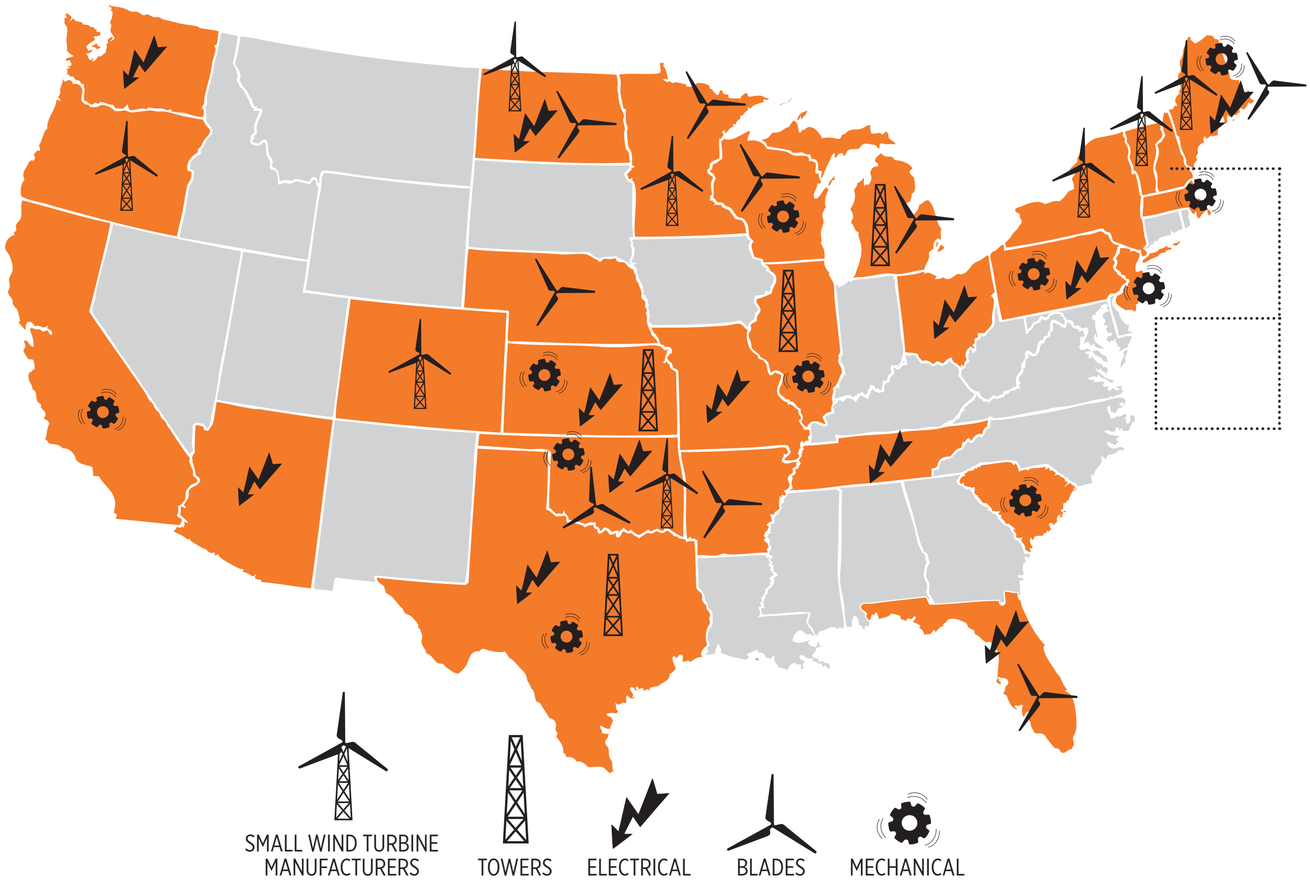

Figure 20. States with small wind manufacturing

10.0 Outlook

Status and growth of the different sectors within the distributed wind market fluctuates year to year. While overall capacity from domestic small wind sales has been in decline over the past five years, sales of the smaller units, 10 kW and less in size, have been steady or have increased in the past three years. Many of these small turbine units are for off-grid applications, and demand for off-grid power is less sensitive to changes in policy or market conditions. Small wind exports doubled from 2014 to 2015, but 2016 small wind exports were comparable to 2014. The reductions and restructuring of incentives in top export destinations such as the United Kingdom and Italy have the potential to reduce exports further in the coming years. Mid-size turbines continue to play a minor role in the distributed wind market, with just one installation in 2016 and five in 2015. Growth in the large-scale turbine sector has been uneven in the past four years, but the trend of large, behind-the-meter turbine units to power industrial operations and municipalities continued in 2016 and is expected to continue.

In November 2016, NREL published *Assessing the Future of Distributed Wind: Opportunities for Behind-the-Meter Projects*, a first-of-its-kind study characterizing the potential future market for behind-the-meter, grid-connected distributed wind systems (Lantz et al. 2016). Analysis in the report was conducted using NREL's dWind model, a technology diffusion model that utilizes national datasets to assess project-level economics and deployment considerations for millions of potential distributed wind sites throughout the continental United States (Sigrin et al. 2016).

Results from the *Assessing the Future of Distributed Wind* report suggest there could be a substantial role in the nation's electricity future for behind-the-meter distributed wind. More specifically, the report estimates nearly 42 GW of economic potential[29] for distributed wind in 2018. Locations of this potential are shown in Figure 21.[30]

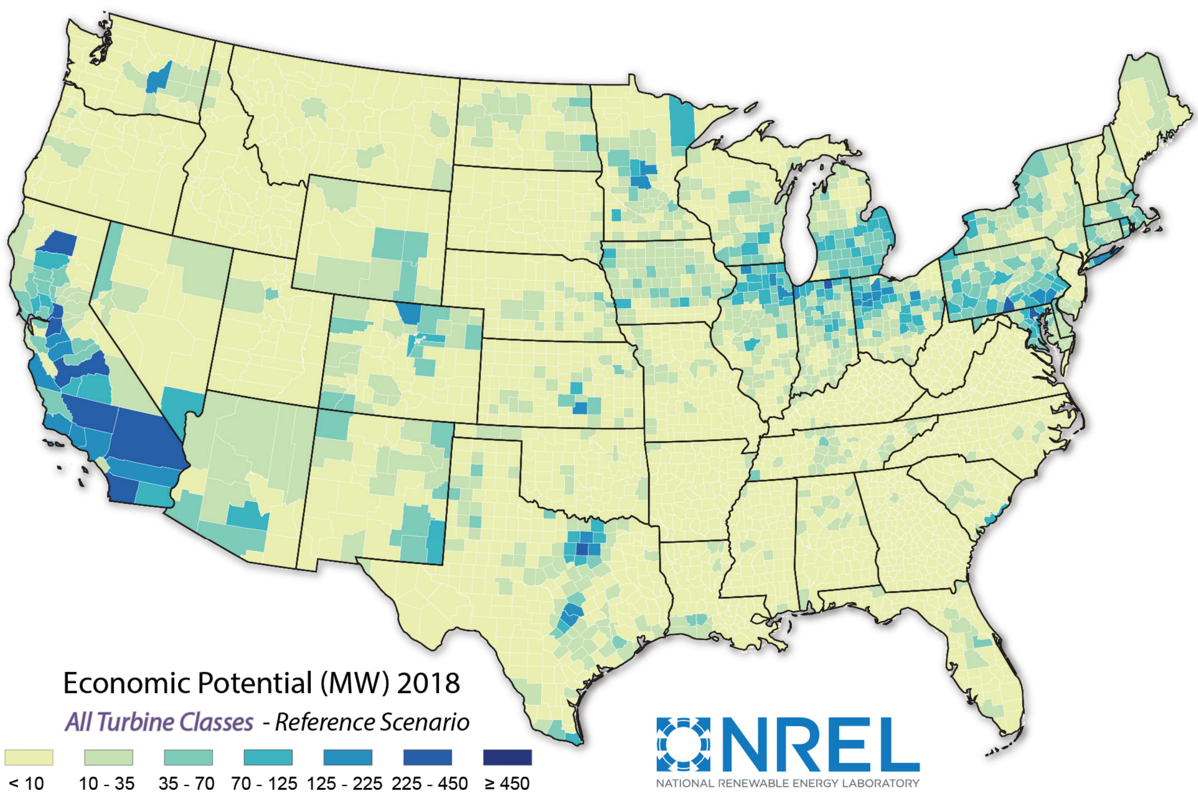

Figure 21. Economic potential map for all turbine classes by U.S. county – reference scenario for 2018

[29] Economic potential is the sum of potential distributed wind capacity installations that could yield a positive net present value (i.e., the value of the project's cash inflows is greater than the value of the cash outflows) for the customer over the life of the wind system. The economic calculations include, but are not limited to, factors such as utility electricity rates, tax credits, technology costs, and net-metering policies. The net present value calculation is a discounted cash flow evaluation for each site, using a 5.4% real ($2014) weighted average cost of capital and 25-year investment horizon. See Lantz et al (2016) for further detail.

[30] The amount of economic potential is mapped by county on an absolute basis, not on a per-capita basis. That is, counties with larger areas may appear more favorable than smaller ones, regardless of differences in the per-capita potential.

For this 2018 scenario, five states (California, Indiana, Ohio, Pennsylvania, and Texas) were observed to have at least 3 GW of economic potential. Though Midwest states in the interior have the best wind resource, they tend to have relatively modest volumes of economic potential as they simply have fewer customers to consider a behind-the-meter turbine. In contrast, both California and New York appear to have relatively high potential due to their favorable retail rates, state-level policies, and relatively large volumes of potential customers.

One interesting trend in the dWind analysis is that industrial sites around the Great Lakes region could be an important market segment for distributed wind systems. Industrial customers in these areas tended to have both good wind resource and the requisite electricity demand and property size to deploy larger MW-scale turbines, which have a lower LCOE than kW-scale turbines. This trend is already playing out as evidenced by the number of large, behind-the-meter turbine units installed in the past two years to power industrial operations and municipalities.

However, to achieve higher levels of deployment, the NREL study noted that several changes to the current market would be necessary. These include not only reductions in technology costs, but also performance improvements, new business models that provide access to low-cost capital and support customer-ready solutions, and increased customer awareness of the benefits of distributed wind technologies (Lantz et al. 2016).

State, federal, utility, and industry players are driving these needed changes in the domestic market with innovative policies, programs, and business models. Many states have taken steps supportive of distributed wind with expanded net-metering policies and RPS changes. DOE's CIP supports new turbine technology design efforts and turbine certification testing (DOE 2017b). In April 2017, Bergey WindPower announced the company had completed the design of a new turbine model to replace its Excel 10 wind turbine model. The next-generation design, the Excel 15, is anticipated to achieve a nearly 50% reduction in LCOE over previous models and is currently undergoing certification testing. In addition, three new small wind turbine models were certified in 2016, underscoring the industry's commitment to product innovation and performance improvement. Finally, new financing deals for companies such as United Wind and One Energy Enterprises LLC signal the growth of and confidence in new business models in the market.

A 10 kW Bergey WindPower Excel 10 wind turbine being serviced.
Photo credit: Bergey WindPower

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APPENDIX A WIND TURBINE MANUFACTURERS AND SUPPLIERS

This report reflects 2016 sales and installations from the manufacturers and suppliers listed below. Others who provided information and/or who are non-U.S.-based and only had non-U.S. sales are recognized in the Acknowledgments section.

Manufacturer	Model Names	Headquarters
Small Wind Turbines (up through 100 kW)		
APRS World, LLC	WT10 / WT14	Minnesota
Bergey WindPower	XL.1, Excel 6, Excel 10R, Excel 10	Oklahoma
Dakota Turbines	DT-30	North Dakota
Hi-VAWT Technology Corporation	DS300, DS700, DS1500, DS3000	Taiwan
Kingspan Environmental Limited	KW6	Ireland
Northern Power Systems	NPS 100, NPS60	Vermont
Pika Energy	T701	Maine
Potencia Industrial	Hummingbird 10	Mexico
Primus Wind Power	AIR 30, AIR X Marine, AIR 40, AIR Breeze, AIR Silent X	Colorado
Skywolf Wind Turbine Corporation	Solar Hybrid DAWT	New York
Ventera Wind	VT10	Minnesota
Xzeres Wind	442SR, Skystream 3.7	Oregon
Wind Turbines Greater than 100 kW in U.S. Distributed Projects		
Gamesa	G97-2.0	Spain
GE Energy	1.7-103, 1.7-100, 2.3-116	United States
Goldwind	GW87/1500	China
Vensys	Vensys 82	Germany
Vergnet	GEV MP-C	France

APPENDIX B METHODOLOGY

The Pacific Northwest National Laboratory (PNNL) team issued data requests to more than 280 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 the sources listed in the Acknowledgments section to tabulate the deployed United States and exported distributed wind generation capacity and associated statistics as of the end of 2016.

A project dataset was created to capture all projects identified by the team as installed in 2016. For distributed wind projects using turbines greater than 100 kW, the PNNL team reviewed the American Wind Energy Association's (AWEA's) database and assessed these projects on a per project basis to determine if they met the U.S. Department of Energy (DOE) definition of distributed wind and should therefore 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 e-mail contact, phone interviews, or both.

All records were compiled in the project dataset with a row for each 2016 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 entered into the dataset records. Small wind turbine sales for which there are project-specific records were added to the project dataset, but most of the 2016 small wind units sold are not able to be tracked on a project basis.

The PNNL team also reviewed and cross-checked wind project listings published by Open Energy Information, Federal Aviation Administration, U.S. Geological Survey, U.S. Energy Information Administration, U.S. Environmental Protection Agency, and other sources.

Installation dates for any projects identified that were not already in AWEA records or reported by manufacturers or agencies were verified and added to the project dataset. Projects reported for 2016 were cross-checked against previous records to avoid double counting.

U.S. sales presence is defined as manufacturers and suppliers documenting at least one sale in the United States in 2016. For small wind turbines, this study reports capacity figures for the same calendar year as the reported sales by the manufacturers and suppliers for the purpose of tallying annual deployed capacity. For turbines greater than 100 kW, the annual deployed capacity is the sum of the distributed wind projects from the AWEA database for the calendar year.
Cross-referencing data sources allows for greater certainty, but a data gap remains regarding 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 basis. Project records are used to allocate capacity values across the states.

The 2016 Distributed Wind Market Report is the DOE's fifth annual report. Project records from 2016 and past years, along with other collected data, have been consolidated to produce a master project dataset. 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 and by year were adjusted for this year's report as a result of this effort, so cumulative values may differ slightly from what was reported in past years.

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

The PNNL team used a variety of public (as listed in the Acknowledgments section) and some private sources of data to compile the installed costs. In some instances, installed cost figures are estimated based on reported incentive values.

Data requested for 2016 included the number of units sold of each model both within and outside the United States, project locations (city or county or coordinates), estimated installed costs and O&M costs per year, energy production data or estimates, name of installer or developer, power purchaser/utility, tower heights and types, top export markets, customer type, breakdowns of project and wind turbine cost components, incentive funding, project financing mechanisms, interconnection types, and ownership structures. The level to which all of these questions were answered varied among responders. Thus, sample sizes are included with certain analysis presentations as needed.

Levelized cost of energy (LCOE) calculations in Section 7.0 used the following formula[31]:

$$\text{LCOE} = \frac{(\text{FCR x ICC})}{\text{AEPnet}} + \text{AOE}$$

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 ($)
	AEPnet	=	net annual energy production (kWh/yr)
	O&M	=	levelized O&M cost ($/kWh)

Average O&M costs discussed in Section 5.4 and used in the LCOE calculations were derived from reports from installers collected over the past three years. The average values account for how many of each turbine model an installer has serviced (i.e., more weight was given to the reported O&M cost for a particular turbine model from an installer who has serviced 30 of those models than the cost reported from an installer who has only serviced one of that model). The estimated yearly O&M costs equated to roughly $70/kW for turbines less than 5 kW, $44/kW for 5 to 10 kW, $22 to 44/kW for 11 to 100 kW, $30/kW for 101 to 999 kW, and $50/kW for greater than 1 MW.

[31] NREL's LCOE formula includes a levelized replacement cost that is excluded here.

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