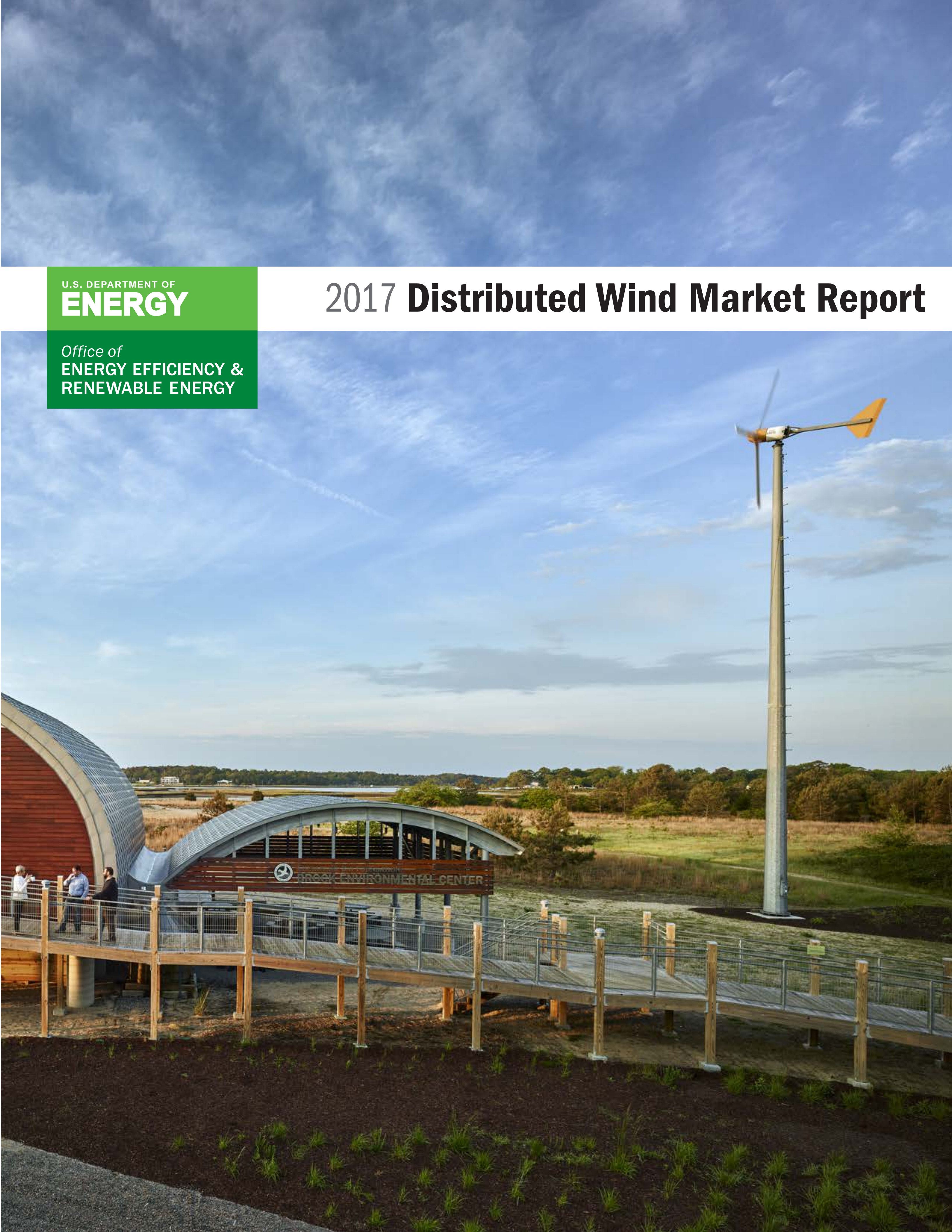

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

2017 Distributed Wind Market Report

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Acronyms

AWEA	American Wind Energy Association
DOE	U.S. Department of Energy
EIA	Energy Information Administration
FIT	feed-in tariff
GE	General Electric
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IRS	Internal Revenue Service
ITC	investment tax credit
LCOE	levelized cost of energy
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
PNNL	Pacific Northwest National Laboratory
PTC	production tax credit
PV	photovoltaic
REAP	Rural Energy for America Program
SWCC	Small Wind Certification Council
TEM	technical experts meeting
USDA	U.S. Department of Agriculture
USVI	U.S. Virgin Islands
VAWT	vertical-axis wind turbine

Executive Summary

Cumulative U.S. distributed wind installed capacity for 2003 to 2017 now stands at 1,076 MW from over 81,000 wind turbines across all 50 states, Puerto Rico, the U.S. Virgin Islands, and Guam.

In 2017, 21 states added 83.7 MW of new distributed wind capacity, representing 3,311 units and $274 million in investment, driven by large-scale turbines installed to power a variety of distributed generation needs.

Of the 83.7 MW, 78 MW came from distributed wind projects using turbines greater than 1 MW, 4 MW came from projects using turbines 101 kW to 1 MW in size, and 1.7 MW came from projects using turbines up through 100 kW. The total of 82 MW from turbines greater than 100 kW represents $262 million in investment. This notable increase in 2017 from 43 MW in 2016 and 23.7 MW in 2015 is due to the significant amount of distributed wind projects using turbines greater than 1 MW installed behind the meter and to serve utility loads on local distribution grids, particularly in Iowa.

Iowa led the nation in installed distributed wind capacity in 2017 with 63.5 MW. Iowa pulled ahead of Texas and Minnesota in 2017 and with 192.7 MW now leads the nation in cumulative distributed wind capacity.

Federal tax credit expiration dates are likely drivers of many of the large-scale projects. Renewable energy project developers teamed with tax equity partners to develop many of these projects.

A total of 1.7 MW of small wind (turbines up through 100 kW) capacity was deployed in the United States in 2017, representing 3,269 units and $11.5 million in investment. Driven by an unstable policy environment and continued competition from low-cost solar photovoltaic (PV) systems, this 1.7 MW continues the downward installed capacity trend from 2.4 MW in 2016 and 4.3 MW in 2015. However, driven by the less than 1-kW turbine size segment, small wind turbine unit sales have increased from 2,560 units in 2016 and 1,695 units in 2015.

The global small wind industry has experienced a contraction as policy programs change and impact U.S. and foreign-based small wind manufacturers. In 2017, the Chinese domestic market had only 15 small wind turbine manufacturers reporting sales, down from 17 in 2016 and 28 in 2014. United Kingdom-based manufacturer, Gaia-Wind, entered liquidation proceedings in March 2018 citing the uncertainty of the United Kingdom feed-in-tariff program as the leading cause of its closure. The Italian feed-in tariff for distributed wind, which drove sales, expired in 2017. With Italy being its primary export market for the past few years, U.S.-based manufacturer Northern Power Systems temporarily suspended its distributed wind manufacturing activities until late 2018, when it anticipates the implementation of the new Italian feed-in tariff.

Small wind exports from U.S.-based manufacturers dropped to 5.5 MW in 2017 representing a $42 million investment, down from 10.3 MW and $62 million in 2016 and a peak of 21.5 MW and $122 million in 2015. The top reported export markets in terms of capacity were Italy and Japan, driven by their feed-in-tariff programs.

The Bipartisan Budget Act of 2018 (Public Law 115-123) reinstated the Residential Renewable Energy Tax Credit for small wind turbines placed in service 2017 through 2021 and extended the Business Energy Investment Tax Credit for small wind projects that start construction by the end of 2022. These extensions, both with credit value phase-down schedules, provide near parity to the solar PV tax credit, which was passed into law at the end of 2015. The reinstated Residential Renewable Energy Tax Credit and extended Business Energy Investment Tax Credit could bolster the small wind market in the near term.

The combined value of U.S. Department of Agriculture Rural Energy for America Program grants, Section 1603 grants, and state rebates, production-based incentives, and production tax credits given to distributed wind projects in 2017 was $13.3 million. This is comparable to recent years ($12.8 million in 2016 and $10.6 million in 2015), but significantly lower than the peak of $100 million in 2012.

A total of 16 different small wind turbine models are certified to the American Wind Energy Association standard or International Electrotechnical Commission standards as of May 2018, with one new turbine model completing certification in February 2018. Certification requirements are increasingly common in the global market. Certification is consistent with industry and U.S. Department of Energy goals to promote the use of proven technology; raise the competitiveness of small wind; and increase consumer, government agency, and financial institution confidence and interest in distributed wind.

The average cost of small wind projects installed in 2017 was $10,117/kW based on 672 kW of rated capacity from 41 turbines. In 2016, the average small wind cost was $9,777/kW based on 1,174 kW of rated capacity from 57 turbines.

The average per kW cost of distributed wind projects using turbines greater than 100 kW installed in 2017 was $3,006/kW based on seven projects representing 46.1 MW and 20 turbines in five states. The average cost for 2016 projects was $3,910/kW (eight projects representing 11.3 MW and eight turbines in four states and Guam).

For a sample of projects, the small wind average LCOE after incentives was 23¢/kWh, the mid-size turbine project average LCOE after incentives was 28¢/kWh, and the large-scale turbine project average LCOE after incentives was 4¢/kWh. The small wind three-year average capacity factor was 16%, the mid-size turbine project three-year average capacity factor was 20%, and the large-scale turbine project three-year average capacity factor was 32%.

A total of 78% of the installed distributed wind capacity documented for 2017 serves utility loads on local distribution grids. Residential and agricultural installations accounted for most of the individual 2017 projects (35% and 25%, respectively), but only roughly 2% of the total distributed wind capacity installed in 2017.

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1 Introduction

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

Distributed wind systems can be at homes, farms and ranches, businesses, public and industrial facilities, or other sites to serve all or a portion of the local energy consumption. These systems can be grid-connected or off-grid[1] to electrify a site not connected to a centralized grid. Distributed wind systems can also connect directly to a local grid[2] to support grid operations and local loads. Distributed wind is differentiated from wholesale power that is generated at large wind farms and sent via transmission lines to substations for distribution to loads and distant end users.

Grid-connected distributed wind systems can be physically or virtually on the distribution grid or on the customer side of the meter. Virtual (or remote) net metering is a billing arrangement that allows multiple energy customers to receive net metering credit from either 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 how and where the distributed energy generation is used, rather than turbine or project size, the distributed wind market includes wind turbines and projects of many sizes. For example, distributed wind systems can range from a less than 1-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 wind turbines at a university campus, at a manufacturing facility, or connected to the distribution system of a local utility.

1.1 Purpose of Report

The annual Distributed Wind Market Report supports DOE's effort to accelerate cost-effective and responsible deployment of distributed wind systems across the United States, raise the quality of installed distributed wind products, and grow the nation's domestic energy industry. In contrast to DOE's annual Wind Technologies Market Report which concentrates on U.S. wind projects using turbines greater than 100 kW, this Distributed Wind Market Report analyzes distributed wind projects of all sizes and details the U.S. small wind market. This report provides key information on current market conditions and regulatory environments to help stakeholders increase the cost competitiveness of distributed wind systems and build better turbines and components. Such improvements lead to improved grid integration and increased customer and utility confidence in distributed wind systems.

Distributed energy offers solutions to concerns about energy security, tighter emissions standards, and transmission bottlenecks. When incorporated into a microgrid, distributed energy can provide resilience against blackouts and brownouts.

Further, distributed wind supports the nation's manufacturing economy. U.S.-based small wind turbine manufacturers rely on a largely U.S. supply chain for wind turbine components. These manufacturers supply most of the small wind turbines deployed domestically and also export to the global market.

1.2 Wind Turbine Size Classification

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

- Wind turbines up through 100 kW (in nominal, or nameplate, capacity)—referred to in this report as "small wind"

1 Off-grid wind turbine systems directly serve on-site loads and typically include battery backup or other energy storage because they lack a connection 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.

- Mid-size wind turbines 101 kW to 1 MW
- Large-scale wind turbines greater than 1 MW.

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

The nominal, or nameplate, capacity of a wind turbine is what manufacturers use to describe, or name, their wind turbine models. For projects using turbines greater than 100 kW, the project's total nominal power capacity is used in the cost per kW and related analyses. For small wind, this report uses the total rated power capacity of the project in the cost per kW and related analyses, rather than nameplate capacity. A certified small wind turbine's rated capacity is its power output at 11 meters per second (m/s) per the American Wind Energy Association (AWEA) 9.1-2009 Standard. For turbines that are not certified, the power output at 11 m/s is assigned as the turbine's rated, or referenced, capacity. Ratings for the small wind turbine models included in this report are listed in Appendix B.

1.3 Data Collection and Analysis Methodologies

To produce this report, Pacific Northwest National Laboratory (PNNL) issued data requests to turbine manufacturers and suppliers, developers, installers, operations and maintenance (O&M) providers, state and federal agencies, utilities, and other stakeholders.

A project dataset was created to capture all projects installed in 2017 identified through the data request process. For distributed wind projects using turbines greater than 100 kW, the PNNL team reviewed the AWEA's database and other sources (e.g., the Federal Aviation Administration database) and assessed each project to determine if it met DOE's definition of distributed wind and should, therefore, be included in the distributed wind project dataset. Additional data sources (e.g., U.S. Energy Information Administration) are also consulted to supplement project records.

Small wind project records from manufacturers and suppliers, O&M providers, utilities, and agencies obtained through the data request process were also added to the project dataset. However, many 2017 small wind units sold are not tracked at the project level, such as off-grid turbine units purchased from dealers, and are therefore not included in the project dataset. The project dataset is used to make year-to-year comparisons; allocate capacity values across states; analyze installed costs; identify incentive funding levels; and characterize distributed wind customers, types of turbines and towers, and project locations (i.e., grid-tied or off-grid and behind the meter or on the local distribution grid).

PNNL also created a separate small wind sales dataset based on manufacturers' sales reports. The reported total number of small wind turbine units and capacity deployed, domestically and abroad, come 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 to tally annual deployed capacity. Appendix B details the data collection process and analysis methodology.

2 U.S. Distributed Wind Deployment

From 2003 through 2017, over 81,000 wind turbines were deployed in distributed applications across all 50 states, Puerto Rico, the U.S. Virgin Islands (USVI), and Guam, totaling 1,076 MW in cumulative capacity (Figure 1).[4] In 2017, 21 states added 83.7 MW of new distributed wind capacity, representing 3,311 units and $274 million in investment.[5]

In 2017, 1.7 MW of small wind was deployed in the United States, representing 3,269 units and $11.5 million in investment. Driven by an unstable policy environment and continued competition from low-cost solar photovoltaic (PV), this continues the downward trend for small wind capacity of recent years.

Of the 83.7 MW added in 2017, 82 MW came from distributed wind projects using turbines greater than 100 kW (78 MW from large-scale and 4 MW from mid-size), representing $262 million in investment. This significant increase from 43 MW in 2016 and 23.7 MW in 2015 is due to a significant amount of distributed wind installed to serve loads on local distribution systems in Iowa.

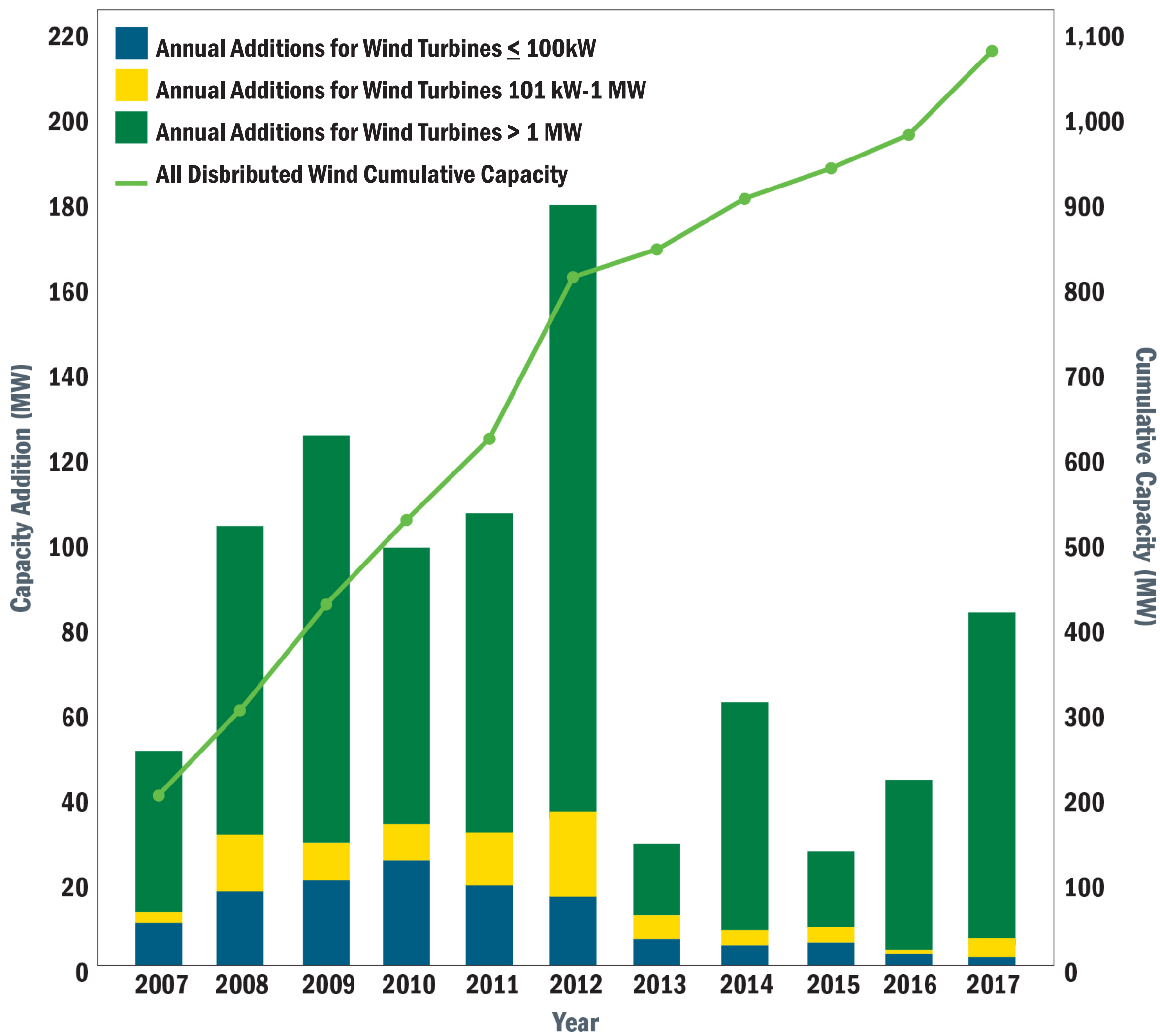

Figure 1. U.S. distributed wind capacity

4 The data presented in the figures are provided in an accompanying data file available for download at **http://energy.gov/eere/wind/downloads/2017-distributed-wind-market-report**.

5 All dollars are in 2017 dollars unless noted. Annual and cumulative capacity values are based on nominal turbine capacity sizes.

2.1 Top States for Distributed Wind: Annual and Cumulative Capacity

New distributed wind projects were documented in 21 states in 2017 (Figure 2) and have been documented in all 50 states, the District of Columbia, Puerto Rico, the USVI, and Guam since 2003 (Figure 3).

Iowa, Ohio, and California led the United States in new distributed wind power capacity in 2017 as a result of large-scale turbine behind-the-meter projects and large projects on the distribution grid serving local loads.

With the New York State Energy Research and Development Authority (NYSERDA) incentive program, New York State led the nation for small wind capacity deployment in 2017, accounting for 37% of the documented small wind capacity for the year. The NYSERDA small wind turbine incentive program is set to expire at the end of 2018.

Iowa, Texas, and Minnesota are the top states for overall distributed wind capacity deployed since 2003. Figure 4 shows the states with cumulative distributed wind capacities greater than 20 MW. With 63.5 MW of installed capacity in 2017, Iowa pulled ahead of Texas and Minnesota in cumulative distributed wind capacity. Iowa, Nevada, and Alaska remain the top states for cumulative installed small wind capacity. Figure 5 shows the states with cumulative small wind capacities greater than 2 MW.

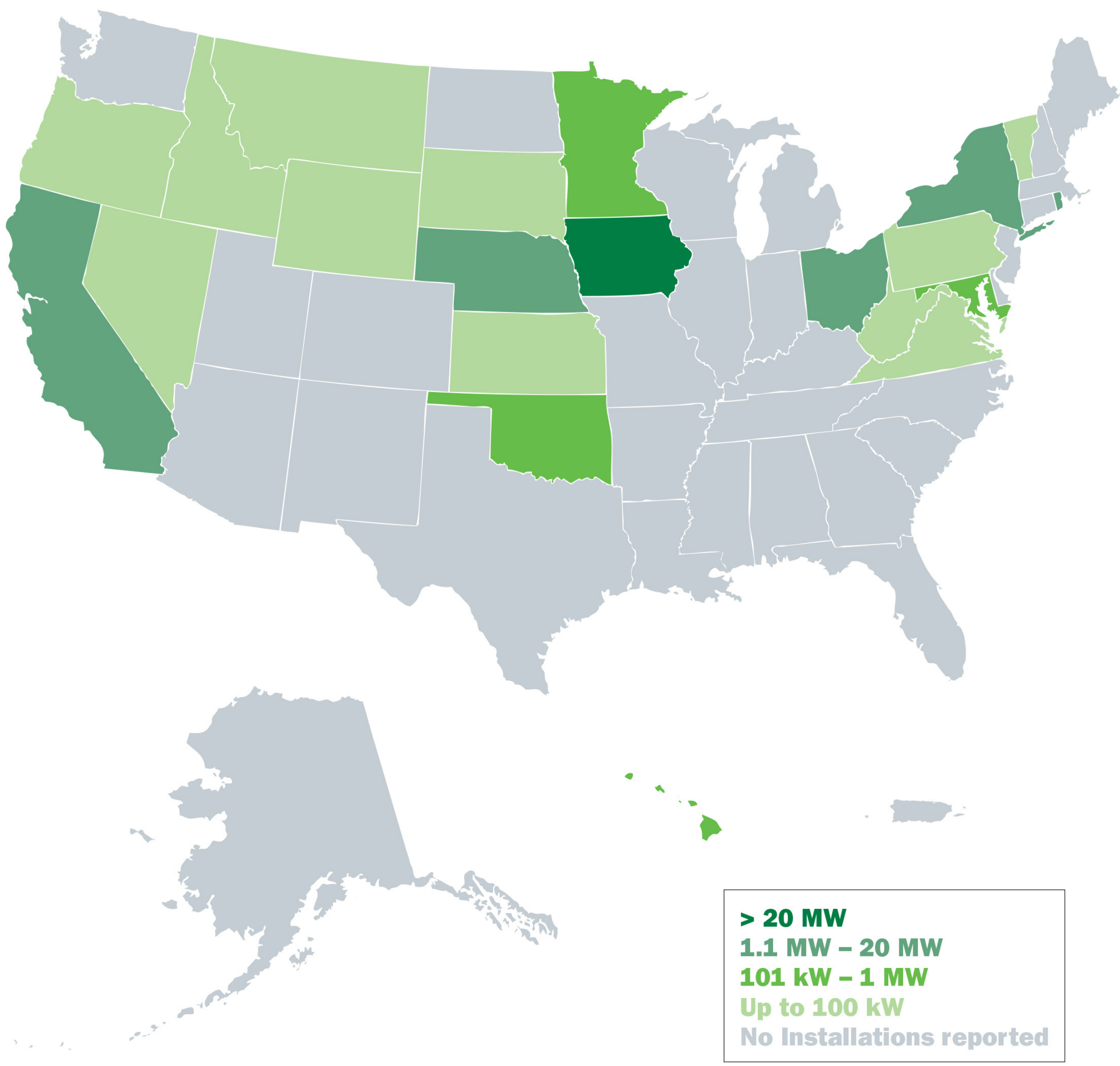

Figure 2. 2017 U.S. distributed wind capacity additions by state

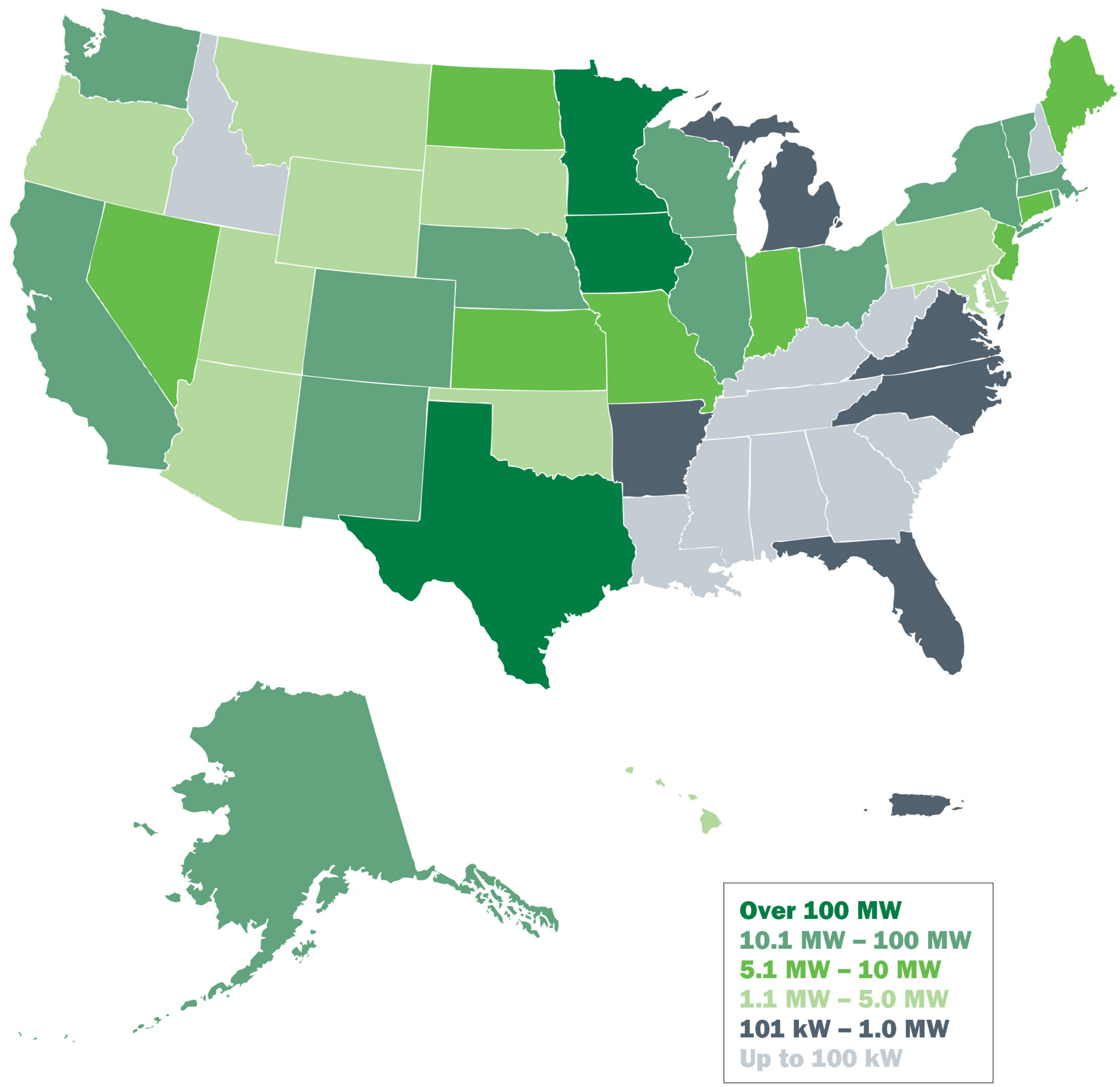

Figure 3. 2003–2017 cumulative U.S. distributed wind capacity by state

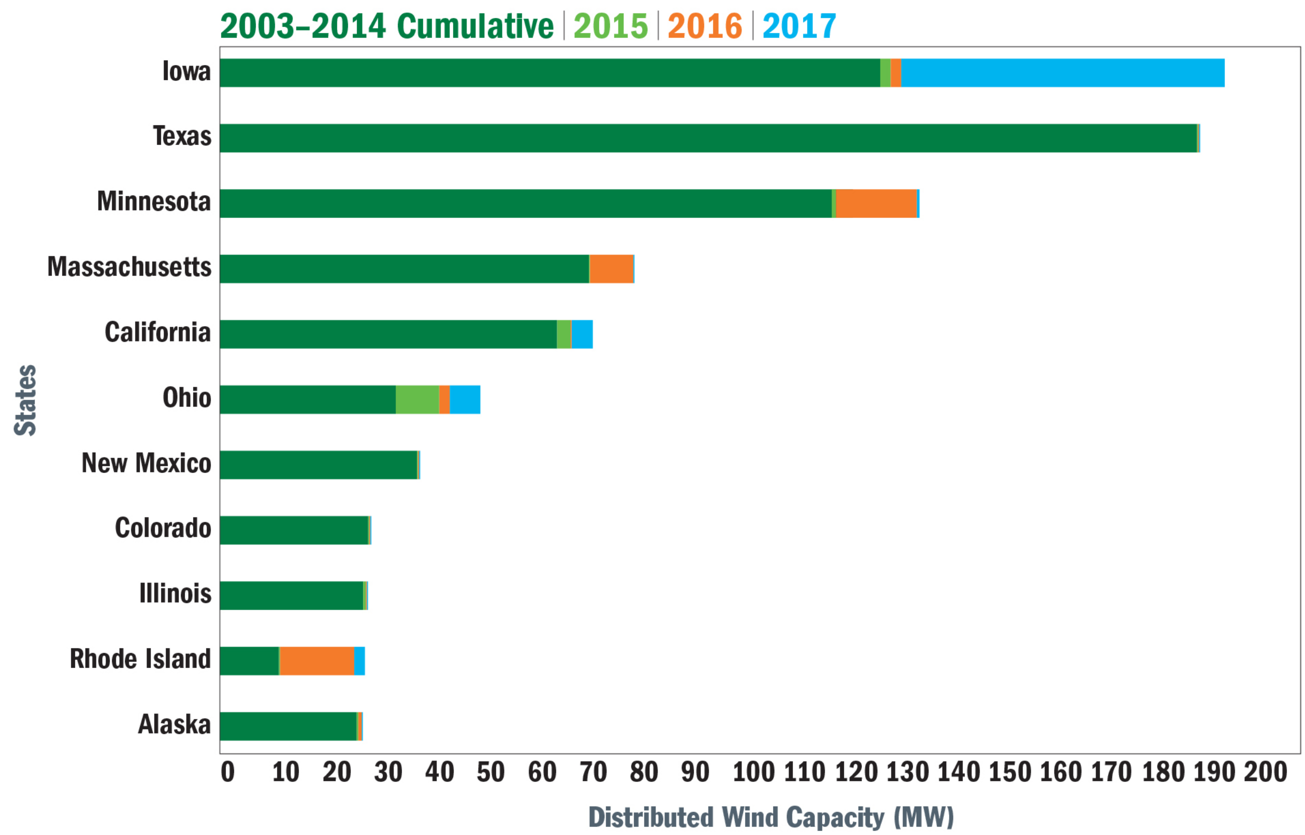

Figure 4. Top states for distributed wind capacity, 2003–2017

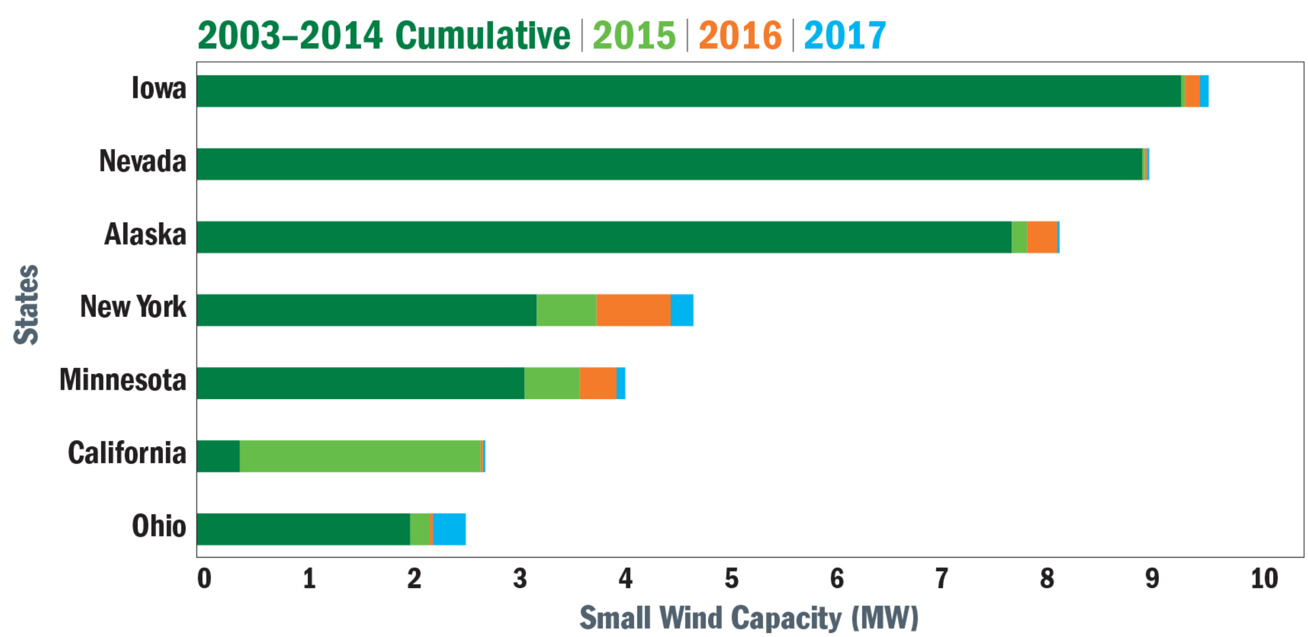

Figure 5. Top states for small wind capacity, 2003–2017

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

The 11 small wind turbine manufacturers with a 2017 U.S. sales presence accounted for in this report consist of seven domestic manufacturers headquartered in seven states (Arizona, Colorado, Minnesota, North Dakota, Oklahoma, Oregon, and Vermont) and four 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 five foreign manufacturers who replied to PNNL's data request, four reported sales in the United States in 2017—Hi-VAWT Technology Corporation (Taiwan), C&F Green Energy (Ireland), Britwind Limited (United Kingdom), and Eocycle (Canada). In 2016, three non-U.S.-based manufacturers reported sales in the United States—Hi VAWT Technology Corporation (Taiwan), Kingspan Environmental Limited (Ireland), and Potencia Industrial (Mexico). In 2015, two different 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.

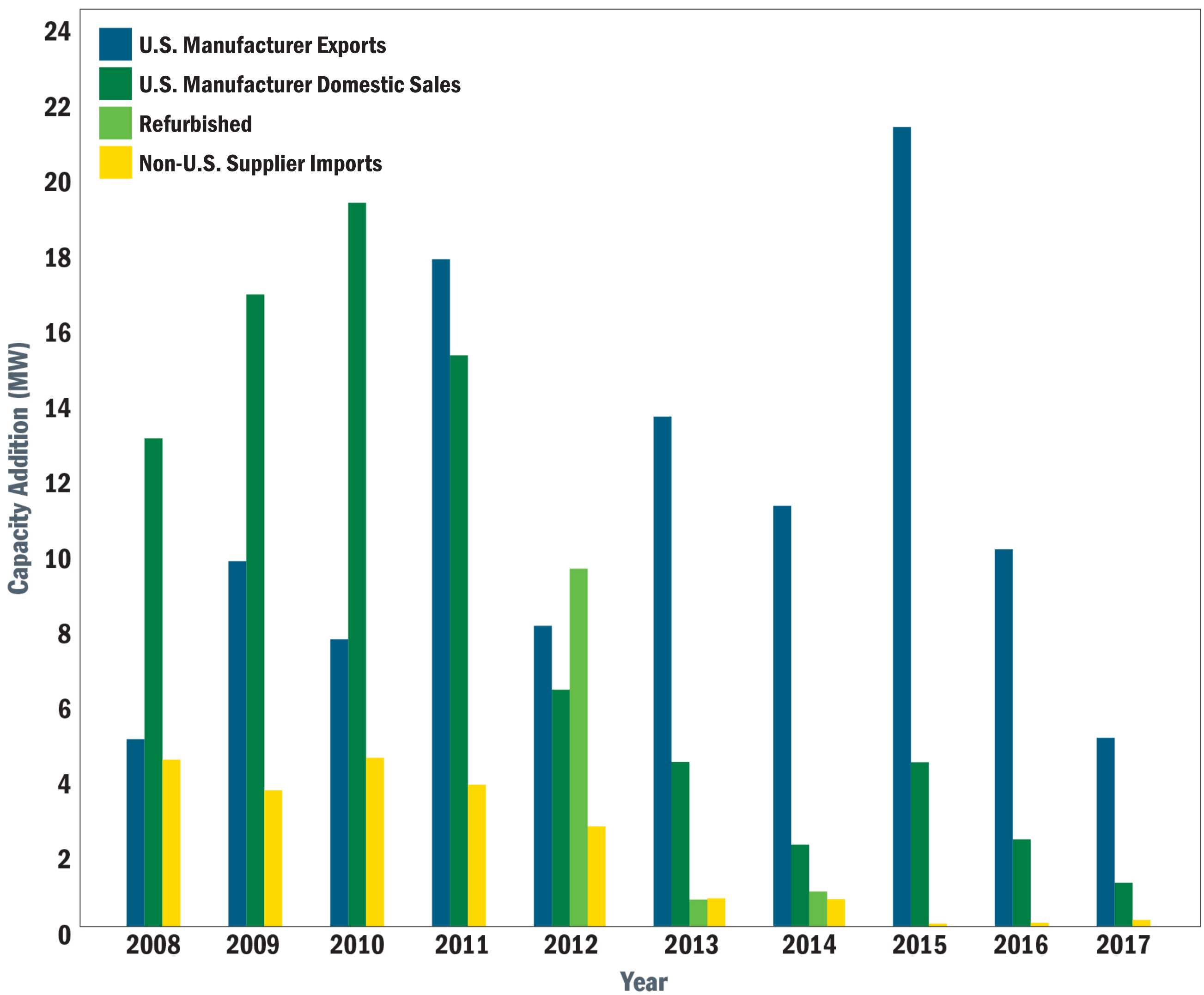

Figure 6. U.S. small wind turbine sales and exports, 2008–2017

Since 2012, the number of small wind turbine manufacturers both operating and participating in the U.S. market has decreased, and the overall small wind industry has contracted. In 2012, 31 manufacturers reported U.S. sales; however, only 11 manufacturers reported sales in the United States in 2017. At least one manufacturer, Pika Energy, ceased sales of its wind turbine products in 2017 and is now solely focused on solar PV and energy storage.

This contraction in the number of manufacturers is not limited to United States. The Chinese domestic market has seen a similar reduction in the number of manufacturers in the market (see Section 3.4.4). Further, U.K.-based manufacturer, Gaia-Wind, entered liquidation proceedings in March 2018, citing the uncertainty of the United Kingdom feed-in-tariff (FIT) program as the leading cause of its closure (Hill 2018).

The top four U.S. small wind turbine manufacturers, based on 2017 sales in terms of capacity (MWs of domestic sales and exports), in order were Northern Power Systems of Vermont, Xzeres Wind of Oregon, Primus Wind Power of Colorado, and Bergey WindPower of Oklahoma.

For turbines greater than 100 kW, nine different models for 17 distributed wind projects were supplied by seven manufacturers and suppliers[6] in 2017. Two of these seven manufacturers were U.S.-based[7] (i.e., General Electric [GE] Renewable Energy and Aeronautica), four were importers (i.e., Goldwind [China], HZ Windpower [China], Nordex [Germany], and Vensys [Germany]), and one was a foreign refurbished turbine supplier (i.e., Free Breeze [Canada]).

Similar to the small wind industry, the number of mid-size and large-scale turbine manufacturers and suppliers with installations in the United States has contracted since 2012, and foreign manufacturer representation changes from year to year. In 2012, 27 manufacturers supplied 33 different mid-size and large-scale turbine models for 69 U.S. distributed wind projects. However, the number of manufacturers and suppliers in 2017 has increased since 2016, from five to seven. HZ Windpower, Nordex, Free Breeze, and Aeronautica had turbines used in recorded distributed wind projects in 2017, but not 2016 or 2015. GE Renewable Energy has been the only consistent U.S.-based manufacturer of large-scale turbines used in distributed wind projects for the past six years. Goldwind is the sole turbine supplier for One Energy Enterprises LLC, a distributed wind project developer based in Ohio. Otherwise, no single mid-size or large-scale turbine manufacturer appears to have a strong position in the U.S. distributed wind market.

3.1 Domestic Sales

The 1.7 MW of small wind sales recorded in 2017 represent 3,269 units and $11.5 million in investment. This continues the downward trend of small wind capacity deployed in recent years, although the number of small wind units has increased, primarily in the less than 1-kW turbine size segment. The demand for remote power, mainly provided by the smaller, off-grid wind turbine units, is less sensitive to market conditions.

A total of 2.4 MW of small wind was deployed in 2016 (2,560 units and over $14 million in investment), 4.3 MW 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).

Figure 6 shows annual domestic, export, refurbished, and import sales of small wind turbines. No refurbished small wind turbine sales were reported for 2017.[8] U.S. small wind manufacturers accounted for 94% of the 2017 U.S. domestic small wind sales. While U.S.-based small wind manufacturers still account for most U.S. small wind sales, a slight increase in the number of foreign manufacturers with a U.S. sales presence in 2017 dropped U.S. manufacturers' market share from the 98% reported in 2016 and the nearly 100% reported in 2015.

A total of 82 MW of distributed wind capacity was installed in 2017 using turbines greater than 100 kW, up from 43 MW in 2016 and 23.7 MW in 2015. This significant growth can be attributed to the increase in distributed wind projects using large-scale turbines (greater than 1 MW), which rose to 78 MW in 2017 from 43 MW in 2016 and 21 MW in 2015.

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6 In relation to manufacturers, suppliers refer to remanufacturers of domestic and imported turbines.

7 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.

8 Most refurbished wind turbines sold in 2012 were installed in Nevada and received Section 1603 funding and NVEnergy incentive program funding. There have been few to no refurbished small wind turbine sales since 2012

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

The main driver for this increase in distributed wind projects using large-scale turbines, both in general and for utilities, is likely the anticipated expirations of the federal production tax credit (PTC) and ITC, set to expire in 2019 and 2022, respectively. To finance and develop projects, many renewable energy project developers team with tax equity partners which allows the equity partners to obtain the project's tax benefits (NACE 2016; Creston News 2016).

Of the 78 MW of projects using turbines greater than 1 MW, 65 MW were for utilities. Of that 65 MW, 63 MW were installed in Iowa. Because of its strong wind resources and favorable policies, Iowa is ranked number one in the United States for distributed wind capacity (see Figure 4), number one for small wind capacity (see Figure 5), and number three for overall installed wind capacity (AWEA 2018).

3.2 Imports

Reported sales in the United States from foreign small wind manufacturers continued to be low in 2017 with only four foreign manufacturers reporting U.S. sales. Non-U.S.-based small wind manufacturers reported more sales in other markets, primarily Japan, Italy, United Kingdom, and China.

While U.S. manufacturers dominate small wind domestic sales, the mid-size and large-scale turbine markets rely more on imports. Two U.S.-based manufacturers—GE Renewable Energy and Aeronautica—supplied mid-size and large-scale turbines for U.S. distributed wind projects in 2017. Of the capacity installed in 2017, GE turbines accounted for 10.8 MW and Aeronautica turbines for 750 kW. The five foreign manufacturers and suppliers represented a combined 70.3 MW (i.e., Nordex, 30 MW; HZ Windpower, 28 MW; Goldwind, 6 MW; Vensys, 3 MW; and Free Breeze, 3.3 MW with refurbished Vestas).

3.3 Exports

U.S. small wind turbine manufacturers also export to international markets. The top reported export markets in terms of capacity were Italy and Japan, driven by their FIT programs described in Section 3.4.

Four U.S.-based small wind manufacturers exported turbines totaling 5.5 MW in capacity with an estimated value of $42 million in 2017. Figure 7 shows the primary reported countries that received U.S. small wind exports in 2017. The 5.5 MW is down from 10.3 MW, representing a $62 million in investment in 2016 from six manufacturers, after a peak in 2015 at 21.5 MW of small wind exports from six manufacturers valued at $122 million.

3.4 Global Small Wind Market

In 2017, PNNL documented 114 MW of new small wind capacity in 10 countries. This number is about 6% lower than the 122 MW PNNL documented for 2016. Deployment in previously growing markets, such as China and the United Kingdom, have decreased dramatically, dropping 38% and 95%, respectively between 2016 and 2017. Other markets, such as Japan and Italy, have greatly increased their domestic capacities with 200% and 34% growth, respectively.

Total global installed cumulative small wind capacity is estimated to be at least 1.1 GW as of 2017 as shown in Table 1.[9]

[9] In the past, 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; Gsänger and Pitteloud 2016), which has been about 85 MW total on average annually. With that assumption, PNNL's data collection from 10 to 12 countries likely represents 95% of the global market. Country capacity values, including from past years, are updated for each market report as needed based on best available information and reported corrections.

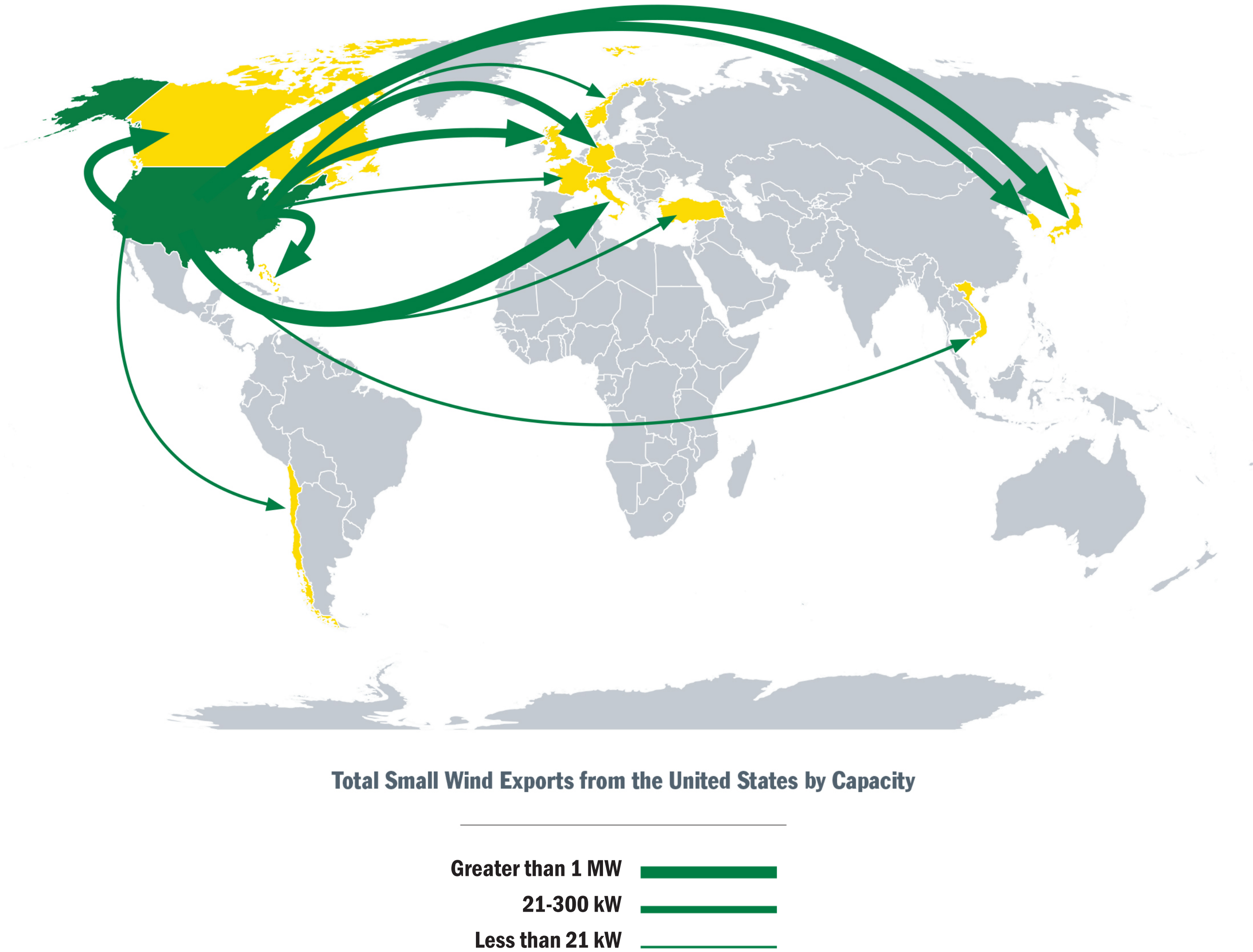


Figure 7. U.S. small wind exports map

In March 2018 at the Danish Technical University, an International Energy Agency (IEA) Technical Experts Meeting (TEM) considered the mid- to long-term worldwide technical and market needs of distributed and community wind. TEM members recommended that IEA expand its efforts beyond current efforts focused on small wind turbines in sites with high turbulence (IEA Wind Task 27). This potentially marks the beginning of a new international task that includes integration, deployment, and social acceptance. Another discussion point at the TEM, which is validated by PNNL data, is that the European markets are becoming much more challenging as they move away from FITs (Tenk 2018).

3.4.1 Italy

With close to 77.5 MW of new capacity installed, the Italian market for small wind (defined in Italy as turbines sized 250 kW or less) continued its upward trajectory in 2017 (ASSIEME 2018). Except for 2015, Italy's small wind market has grown steadily over the past five years with year-to-year growth more than doubling in two out of the past four years. Most of the installed capacity came from turbines sized 200 kW or less (with only four turbines sized greater than 200 kW installed). The FIT, which expired in December 2017, significantly contributed to the increase in installations that reached a cumulative capacity of 189 MW in 2017.

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

	2013 (MW) Installations	2014 (MW) Installations	2015 (MW) Installations	2016 (MW) Installations	2017 (MW) Installations	Cumulative (MW) Installations	Cumulative Year Range
China[a,b]	72.25	69.68	48.60	45.00	27.70	532.81	2007-2017
Japan[c]	*	*	0.36	0.95	2.85	8.43	As of 2017
South Korea[d]	0.01	0.06	0.09	0.79	0.08	4.02	As of 2017
UK[e]	14.71	28.53	11.64	7.73	0.39	140.60	As of 2017
Denmark[f]	1.65	1.28	5.84	4.45	0.96	21.88	As of 2017
Germany[g]	0.02	0.24	0.44	2.25	2.25	30.75	As of 2017
Italy[h]	7.00	16.27	9.81	57.90	77.46	189.43	As of 2017
Canada[i]	*	*	*	*	*	13.47	As of 2017
United States	5.60	3.70	4.30	2.40	1.70	148.00	2003-2017
Brazil[j]	0.03	0.02	0.11	0.04	0.11	0.31	2013-2017
Autralia[k]	*	0.02	0.03	*	0.02	1.46	2001-2017
New Zealand[l]	*	*	*	*	*	0.19	Up through 2015
Global	101.27	119.82	81.22	121.51	113.52	1,091.34	

* Data Not Available
[a] China Wind Energy Equipment Association (CWEEA)
[b] Chinese Wind Energy Association
[c] Japan Small Wind Turbine Associate (JSWTA)
[d] Korea Energy Agency
[e] www.gov.uk, Monthly MCS and ROOFIT degression statistics
[f] www.energinet.dk
[g] Bundesnetzagentur; Bundesverband Kleinwindkraftanlagen; 0-50 kW capacity
[h] www.assieme.eu; 0-250 kW capacity
[i] The Atlas of Canada - Clean Energy Resources and Projects (CERP)
[j] www.aneel.gov.br
[k] www.cleanenergyregulator.gov.au
[l] Sustainable Electricity Association of New Zealand

The Italian market has been the primary export market for Vermont-based Northern Power Systems for the past few years. Because of the uncertainty in the Italian market, Northern Power Systems instituted furloughs at its manufacturing plant in Barre, Vermont. The company expects the Italian government to reinstate the FIT in the fourth quarter of 2018, at which time the company reports it will resume manufacturing (Griffin 2018).

3.4.2 Japan

In 2017, the Japanese government's renewable energy target for wind power in electricity generation remained at 1.7%. Despite this relatively low government target, small wind in Japan has grown significantly. Installations have essentially tripled over the past year, growing from 364 kW in 2015, to 952 kW in 2016, and finally to 2,852 kW in 2017 (Matsumiya 2018) due to the availability of a FIT. Another indicator of the strength of the market is the queue of projects approved for the FIT, which has grown from 31,907 kW in 2016 to 120,443 kW in 2017. The FIT, valued at 55 Yen ($0.51)[10] per kWh for wind projects sized below 20 kW and between 20 and 21 Yen ($0.19–$0.20) per kWh for wind projects sized above 20 kW in 2017, has been a major driver for sales in Japan (IEA 2018). Japan's FIT supported 2 MW of small wind sales by U.S. manufacturers in 2017 alone, an increase from 1.1 MW in 2016 and 1.2 MW in 2015.

3.4.3 United Kingdom

The small wind market in the United Kingdom decreased significantly in 2017. Installations dropped from 7.7 MW in 2016 to just 393 kW in 2017. These numbers reflect a continuous decrease in installations from a peak in 2014, when 28.5 MW of small wind was installed.

[10] This report used Google Finance to convert currency values as of May 29, 2018.

The decrease in installations is most likely a result of the decrease in the FIT rate. Deployment cap sizes may also be preventing interest. The quarterly eligibility cap for small wind projects sized 50–100 kW in 2017 was 300 kW (OFGEM 2018a). The deployment cap for projects sized smaller than 50 kW was between 5,400 and 5,500 kW per quarter in 2017, but only 113 kW of capacity in this size range was commissioned. In late 2017, the United Kingdom's government announced that subsidies for renewable energy, including the FIT, would be canceled after April 2019 (Vaughan 2017). Since the precipitous drop of the FIT rate in late 2015, the FIT rate has continued to marginally decline to 8.60 pence ($0.12) per kWh for wind systems sized up to 50 kW in December 2017, and 5.08 pence ($0.07) per kW for systems sized 50–100 kW (OFGEM 2018b).

In the remaining months before the FIT's planned end, the Office of Gas and Electricity Markets declared that between January and March 2019, rates for small wind would stand at 8.24 pence ($0.11) per kWh for wind systems sized up to 50 kW, and 4.87 pence ($0.07) per kWh for systems sized 50–100 kW (OFGEM 2018c). In 2017, U.S. manufacturers sold 200 kW to the United Kingdom (installations often lag sales reports). This number is down from around 1 MW in 2016 and 5 MW in 2015.

3.4.4 China

In 2017, Chinese small wind manufacturers reported sales of 41.7 MW in capacity. A total of 27.7 MW of small wind turbines were sold in China while 14 MW were exported (CWEEA 2018). This number illustrates a continued downward trend from 2009–2011—when domestic and export sales exceeded 60 MW annually—and is the lowest amount of sales since 2007. Exports have greatly fluctuated over the last 10 years, with a peak of 62 MW in 2010 and a low of roughly 3 MW in 2013. The decline in sales volume is also reflected in the decline of small wind manufacturers in China. In 2017, only 15 small wind turbine manufacturers reported sales, a decrease from 17 in 2016 and 28 in 2014 (Duo 2017).

3.4.5 South Korea

Because of policy changes and local ordinances, the small wind market in South Korea has grown unevenly. In 2017, only 80 kW of small wind installations were reported (KIER 2018) and the cumulative small wind capacity is just over 4 MW. South Korea ended its FIT program in 2012 and replaced it with a renewable portfolio standard (Lo 2017). While the switch from the FIT increased capacities in some renewables, such as biomass co-firing and fuel cell deployment, small wind installations saw a precipitous drop. However, in 2016, a regulation changed, creating a renewable obligation for public institutions that led to 790 kW of small wind installations that year. On the local level, individuals with an interest in installing small wind turbines in South Korea need to get written approval from neighbors within a given radius, which hampers growth prospects in more densely populated areas. In 2017, U.S. manufacturers reported 110 kW of exports to South Korea, consistent with the roughly 100 kW reported in 2016 and an increase from none reported in 2015.

4 Policies, Incentives, and Market Insights

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

4.1 Policies and Incentives

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

Figure 8 shows the number and value of U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) grants, Section 1603 grants[11], and state incentives[12] given in each state for distributed wind projects in 2017. The combined value of all awards equals $13.3 million in nine states.[13] This is comparable to recent years ($12.8 million in nine states in 2016, and $10.6 million in 10 states in 2015), but significantly lower than the peak of $100 million in 2012.

4.1.1 State Policy and Incentive Highlights

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

Net energy metering programs have been available in most states for many years, but a number of states are now exploring next-generation programs, such as value of distributed generation tariffs and other types of successor net energy metering programs. These states include New York, Minnesota, Oregon, Illinois, and California. Other states provide examples of approaches that essentially scale back net metering programs by reducing the compensation for customer-owned distributed generation. States with this approach include Maine, Hawaii, Indiana, Mississippi, and Arizona.

State-level 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. In 2017, the Energy Trust of Oregon discontinued its small wind incentive program after funding two projects (Figure 8), citing the limited wind resource in the service territories eligible for the incentive, concerns about turbine manufacturer reliability and operation and maintenance costs, the disconnect between estimated and actual power generation, and the overall cost of small wind systems compared to solar PV systems (ETO 2018). In contrast, Oregon's neighbor, Washington State, revised and extended its renewable energy cost-recovery incentive program in 2017 to provide a higher payment per-kWh rate for systems with Washington-made components (Spark Northwest 2017). While there has been significant uptake of the incentive for solar PV systems, no distributed wind systems have received this incentive since 2013.

4.1.2 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 tax credit for a portion of the capital costs of eligible renewable energy projects. Small wind's eligibility for the Residential Renewable Energy Tax Credit expired December 31, 2016; however, the Bipartisan Budget Act of 2018 (Public Law 115-123) reinstated eligibility for the tax credit for small wind turbines placed in

[11] The federal ITC was temporarily expanded in 2009 to allow for cash payments in lieu of the tax credit, otherwise known as the U.S. Treasury cash grants or 1603 payments. 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.

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

[13] Incentive funding and commissioning of distributed wind projects often do not overlap. For example, although USDA REAP grants are recorded for this report in the year they are awarded, they are paid after the project is commissioned. 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 2018).

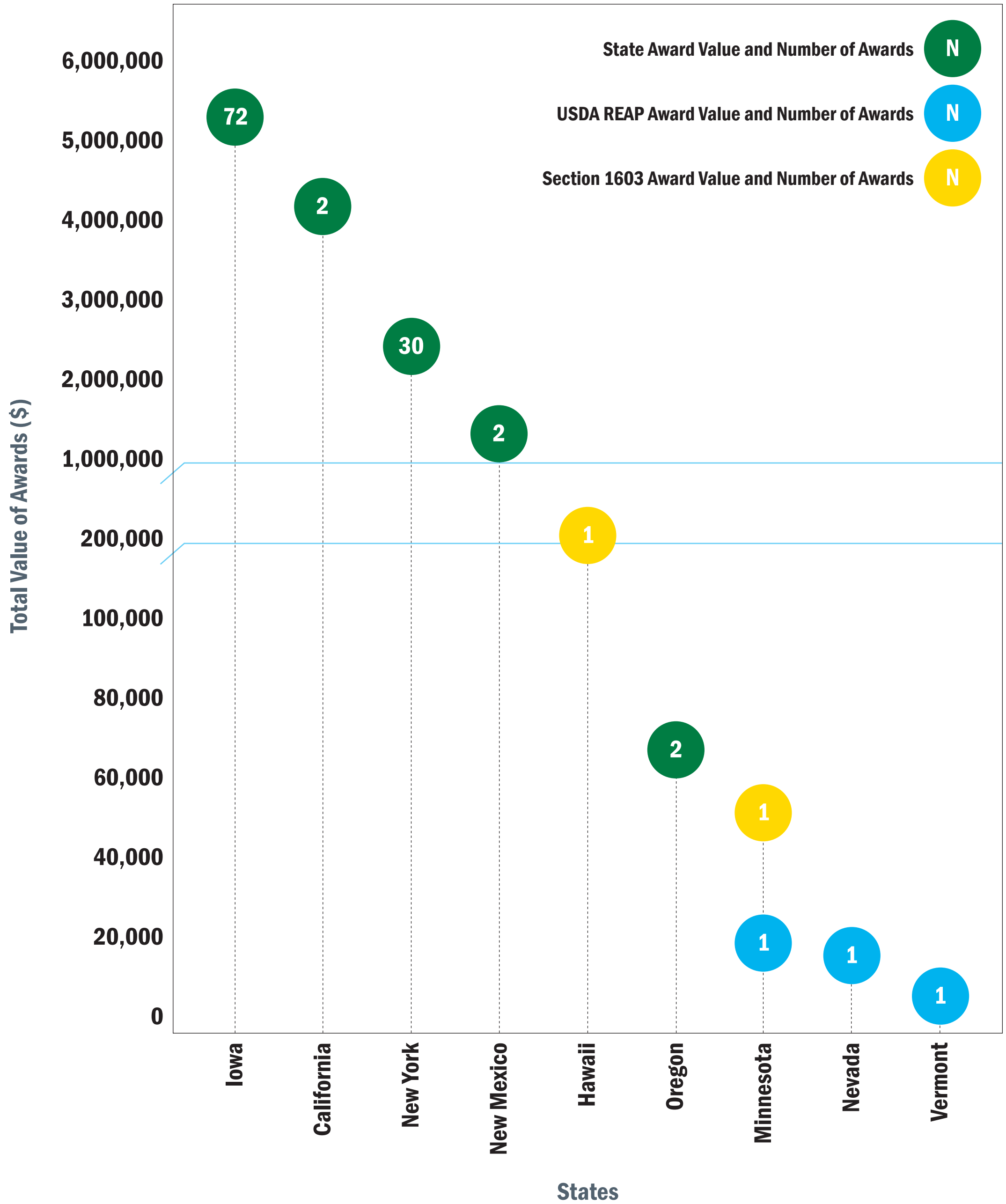


Figure 8. 2017 U.S. distributed wind incentive awards

service in 2017 through 2021. The Act also extended the Business Energy ITC for small wind projects that start construction[14] by the end of 2022. These extensions, both of which phase down the value of the credit over time, provide near parity to the solar PV tax credit passed into law at the end of 2015. For small wind, the Business Energy ITC phase-down schedule is 30% of qualified expenditures for systems that start construction through the end of 2019, 26% in 2020, and 22% in 2021and 2022. For the Residential Renewable Energy Tax Credit, the schedule is 30% for systems placed in service through the end of 2019, 26% in 2020, and 22% in 2021.

[14] The IRS issued guidance in Notice 2017-04 as to what qualifies as "beginning of construction" (IRS 2017).

The Bipartisan Budget Act did not make any changes to the federal renewable electricity PTC (26 U.S.C. § 45). Wind projects that begin construction by December 31, 2019 are still eligible for the PTC, with a phase-down credit value for wind projects that began construction after December 31, 2016. 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.

Information on which tax credit, ITC or PTC, eligible large-scale projects elect, and how many small wind projects have claimed the federal Business Energy ITC or the Residential Energy Tax Credit is not public record as tax records are confidential. Many large-scale projects rely on tax equity partners who invest for the project's tax and financial benefits. PNNL estimates that 970 kW of the small wind projects documented in 2017 were eligible for the 30% federal tax credit (i.e., estimated capacity excludes non-taxable entities), representing a value of roughly $1.9 million based on average small wind installed project costs.

Depreciation is another federal tax-based incentive for wind projects. Tax-paying entities can recover investments for renewable energy projects through the five-year Modified Accelerated Cost-Recovery System depreciation schedule. The depreciation deductions offset taxable income. The Tax Reform Bill (Public Law 115-97, Section 13201), passed into law December 2017, modified the allowance for bonus depreciation, which accelerates the claiming of depreciation. The Tax Reform Bill also removed the "original use" requirement so that property previously placed in service will qualify for 100% bonus depreciation when acquired by another party. With respect to small wind, this change may likely only be relevant to customers who take ownership of small wind turbines from third-party owners, such as a lessor.

4.1.3 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 renewable energy projects for up to 75% of the project's cost or a maximum of $25 million. USDA also issues REAP grants for up to 25% of the project's cost, or a maximum of $500,000 for renewable energy projects. A combination of REAP loans and grants can cover up to 75% of total eligible project costs.

In 2017, USDA REAP funded three wind projects (52.2 kW, five turbines) with $43,586 in grants from four applications that are expected to generate a combined 140,198 kWh of energy annually. This reflects a decrease from 2016, when USDA provided $308,134 in grants for seven wind projects (400 kW, 8 turbines) from 15 applications, and an even greater decline from 2015 levels, when USDA provided $1.4 million in grants for 24 wind projects (2.3 MW, 24 turbines including one 1.5-MW turbine) that were expected to generate 8.7 GWh of energy annually. In addition, there have been no loan guarantees for wind projects since 2015.

Wind projects represented 0.25% of all 2017 REAP grant awards (0.12% of total REAP funding); energy-efficiency projects represented 30% of grant awards (21% of funding); and solar projects represented 65% of awards (57% of funding). Other awards include biomass, geothermal, and hydroelectric projects. In 2016, wind projects represented 0.6% of all REAP grant awards (0.9% of REAP funding).

Since 2003, USDA has awarded over $71 million in REAP wind grants. States receiving the largest share of this funding are Iowa with $23.3 million, Minnesota with $21.2 million, Illinois with $4.1 million, Ohio with $2.9 million, and Oregon with $2.8 million. The top five states in terms of number of wind projects awarded are Iowa with 264 projects, Minnesota with 171, New York with 48, Wisconsin with 45, and Alaska with 30.

Table 2 summarizes the number of REAP grants, grant funding amounts, and loan guarantee values for wind projects from 2012 through 2017.

Table 2. USDA REAP wind awards, 2012-2017

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

As Table 2 shows, the number of awards and grant funding for wind projects has decreased since 2012. 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), likely contributing to the higher number of awards and funding in 2015. Otherwise, the decrease in applications and thus grants is likely due to the same market conditions that are causing the overall decline in small wind installations, such as changing policies, onerous permitting requirements, and lower-cost solar PV as an alternative; however, there are also some REAP-specific conditions that create barriers for distributed wind.

Renewable energy system applications for REAP funding must first go through a technical merit review, with different criteria depending on the project's total cost. For renewable energy systems with a total project cost from \$80,000 to \$200,000, REAP evaluates the project description, resource assessment, project economic assessment, project construction and equipment, and qualifications of key service providers as provided by the applicant (7 CFR 4280.116). If the application is determined to have adequate technical merit, then it is eligible for further consideration for funding. Eligible applications are then scored on seven criteria, one of which is the project's simple payback (7 CFR 4280.120). Available grant funding is then allocated to projects based on their scores.

REAP grant applicants and USDA REAP staff have indicated to PNNL that small wind's high capital cost and lack of access to wind resource data (see Section 6.2) may prevent wind project applications from passing the technical merit review because of the resource and project economic assessment hurdles. Further, shorter payback periods translate to higher scores. If a project's simple payback period is longer than 25 years, it receives zero points for this criterion, lowering its overall score and, thus, its likelihood of receiving funding.

In addition, REAP applications must go through an environmental review process under the National Environmental Policy Act. Projects cannot be awarded funding until the environmental review process has been completed with no adverse findings. Because a wind turbine installation would break the ground's surface, it may have a more complicated environmental review than a rooftop solar PV installation. The review process itself erodes the cost effectiveness of a small wind installation because the process is time consuming and is usually costly to the applicant (Monhemius 2018).

4.2 Market Insights

Beyond policy decisions and changing incentives, other conditions, such as improving technologies and identifying potential markets, affect the growth of the distributed wind market.

4.2.1 Storage

As battery technology costs are decreasing and performance is improving, some small wind industry stakeholders are embracing energy storage as an opportunity to expand or realign business models. Battery technologies, as energy storage, can support a more resilient grid system (Balducci et al. 2018). Energy storage coupled with a distributed energy resource can increase an owner's energy security, particularly in off-grid applications.

Weaver Wind Energy reported that the company spent much of 2017 re-engineering the overall design of its turbines to be "storage-based" systems capable of using various battery chemistries and "grid-interactive" inverters. This is a major strategic realignment for the company with the emerging energy storage market.

Britwind Limited, a U.K.-based small wind manufacturer, noted that past distributed wind installations in the United Kingdom were designed to take advantage of the generous FIT rate; annual FIT payments became a reliable revenue stream for owners. Now that the FIT rate has dropped from its pre-2015 levels, the focus of small wind installations is more on meeting on-site energy consumption needs rather than projects designed just to benefit from the FIT rate. This shift in motivation for customers to generate electricity for their own consumption is buoyed by the increase in availability of storage options, such as lower-cost and better-performing batteries.

And while Northern Power Systems has reported a slowdown in its wind turbine sales, it is seeing increasing activity in its energy storage business (McQuiston 2018). The company designs battery storage systems using batteries with different chemistries from industry suppliers. In 2017, Northern Power Systems implemented a strategy to independently develop energy storage projects in the United States (Griffin 2018).

4.2.2 Market Potential

A 2018 National Renewable Energy Laboratory (NREL) report, *Assessment of the Economic Potential of Distributed Wind in Colorado, Minnesota, and New York* (McCabe et al. 2018), modeled the economic potential of behind-the-meter distributed wind for those three states and found the greatest opportunity for distributed wind market expansion is for agricultural, commercial, and industrial end-use customers in low-density urban centers (e.g., industrial areas), suburban, and rural areas.

These modeled results are reflected in reality by a couple of projects installed for industrial end-use customers in 2017. In 2015, One Energy Enterprises LLC installed 3 MW of behind-the-meter wind capacity to power a Whirlpool Corporation manufacturing facility in Ohio. In 2017, the company installed an additional 6 MW for Whirlpool. In 2016, Buffalo Renewables installed a 100-kW turbine for Triad Recycling & Energy to power its waste-management operations facility outside of Tonawanda, New York. In 2017, the same company installed a second 100-kW turbine for the recycler.

Economic potential is defined as the amount of distributed wind capacity (in MW) that could be deployed at a positive net present value (NPV). Economic viability by turbine count (i.e., number of turbine units) is defined as the aggregate number of sites at which a turbine can be sited at a positive NPV. Turbine counts, or the aggregated system totals, rather than capacity, is a more appropriate metric for small wind systems because a large number of small wind turbine units does not equate to a large amount of capacity (as discussed with Figure 16 in Section 8.1).

The report concluded that the aggregated capacity totals for sites that can generate a positive NPV in 2018 are 360 MW in Colorado, 1,950 MW in Minnesota, and 920 MW in New York. The economically viable aggregated system totals for small wind in 2018 are 1,600 systems in Colorado, 6,000 in Minnesota, and 4,950 in New York (McCabe et al. 2018).

Though actual circumstances leading to turbine adoption may vary between customers, the economic potential metric provides a standardized assessment of when and where distributed wind investment would be a compelling economic decision. The primary variables that inform the economic potential estimates are the quality of wind resource, the amount of on-site electrical load, and site-specific issues such as land availability which may be limited because of tree canopy. Access to low-cost financing and reductions in capital costs stand out as factors that can increase economic potential.

4.2.3 Competitiveness Improvement Project

The DOE Competitiveness Improvement Project (CIP) awards cost-shared grants via a competitive process to manufacturers of small and medium wind turbines. The goals of the project are to reduce hardware costs, make wind energy cost competitive with other distributed generation technologies, and increase the number of wind turbine designs certified to national testing standards. CIP grants fund efforts across three research areas: system optimization, advanced manufacturing, and turbine certification testing. Through five funding cycles, DOE has awarded 21 subcontracts to 11 companies, totaling a $4.9 million DOE investment across the three research areas. A CIP system optimization awardee, Bergey WindPower, is expected to begin sales of its new Excel 15 turbine model in 2018.

4.2.4 Certified Turbines

As of January 2015, small wind turbines must meet either the AWEA Small Wind Turbine Performance and Safety Standard 9.1-2009[15] 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). This certification requirement does not apply to wind projects that opt out of the PTC and instead receive the Business Energy ITC (26 U.S.C. § 48), nor is it codified in the Residential Renewable Energy Tax Credit (26 U.S.C. § 25D) requirements.

[15] 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 U.S. Internal Revenue Service (IRS) guidance, but will likely be replaced by ANSI/AWEA SWT-1 in the future.

Certifying a turbine model to a standard is the industry approach to proving that the turbine model meets the required performance and quality standards. Certification requirements are common across the globe,[16] so small wind manufacturers are pursuing the certification process to qualify for FITs and other incentives in export markets. However, the certification process is a business investment decision that is costly to manufacturers, a reason this is one area the CIP supports. Primus Wind Power, a CIP turbine testing awardee, conducted testing in 2017 and achieved turbine certification for its AIR 40/AIR Breeze turbine model in early 2018.

Table 3 lists the 16 small wind[17] turbine models certified to the AWEA standard or the IEC standards.

Table 3. Certified small wind turbines[18]

Applicant	Turbine	Date of Certification	Certified Power Rating[1] @ 11n.s (kW)	Certification Standard
Bergey WindPower	Excel 10[2]	11/16/2011	8.9	AWEA
Eocycle Technologies, Inc.	E020[3]	3/21/2017	22.5	AWEA
Eveready Diversified Products	Kestrel e400nb[2]	2/14/2013	2.5	AWEA
Kingspan Environmental	KW6[2]	6/17/2013	5.2	AWEA
Lely Aircon B.V.	LA10[2]	1/13/2017	9.6	AWEA
Lely Aircon B.V.	LA30[2]	1/13/2017	27.2	AWEA
Osiris Technologies	Osiris 10[4]	9/27/2013	9.8	AWEA
Pika Energy	T701[2]	1/25/2016	1.5	AWEA
Primus Wind Power	AIR 40/Air Breeze[5]	2/20/2018	0.16	IEC
Sonkyo Energy	Windspot 3.5[4]	10/30/2012	3.2	AWEA
Sumec Hardware & Tools Co. LTD	PWB01-30-48[4]	5/20/2013	1.2	AWEA
Sumec Hardware & Tools Co. LTD	PWA03-44-250[4]	12/26/2012	3.2	AWEA
Sumec Hardware & Tools Co. LTD	PWB02-40-48[4]	5/20/2013	1.7	AWEA
Sumec Hardware & Tools Co. LTD	PWA05-50-280[4]	12/26/2012	5.0	AWEA
Xzeres Wind Corporation	442SR[2]	2/6/2015	10.4	AWEA
Xzeres Wind Corporation	Skystream 3.7[2]	12/19/2011	2.1	AWEA

1 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).
2 Certified by SWCC
3 Certified by SGS
4 Certified by Intertek
5 Certified by DEWI-OCC, UL

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

[17] International and domestic certification standards define wind turbines based on their rotor swept area, rather than their nameplate capacity. For certification purposes, small wind turbines are those having rotor swept areas up to 200 m^2 (approximately 50 to 65 kW) and medium wind turbines are those having rotor swept areas greater than 200 m^2. Three medium wind turbine models, Ghrepower FD21-50, NPS 100-21, and Vergnet GEV MP, have published power performance and acoustics certifications to IEC 61400-12-1 (power) and IEC 61400-11 (acoustics).

[18] Rated sound levels and rated annual energy production values are also available for these certified turbines (IREC 2018; SWCC 2018; Intertek 2018; CESA 2013).

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

Cost data in this section were derived from state and federal agencies, project owners and developers, installers, and news reports.

Data categorization reflects the distributed wind cost taxonomy (Forsyth et al. 2017). The taxonomy, or classification system, allows for consistent names and categories to evaluate distributed wind turbine installation and operation and maintenance costs. It also provides a structure to establish benchmarks.

5.1 Small Wind Installed Costs

The average cost of small wind projects installed in 2017 was $10,117/kW based on 41 turbines totaling 672 kW of rated capacity across seven states.[19] Figure 9 shows the small wind project-specific total installed costs reported for 2017. Costs are before any incentives and include only those 2017 small wind projects for which cost information

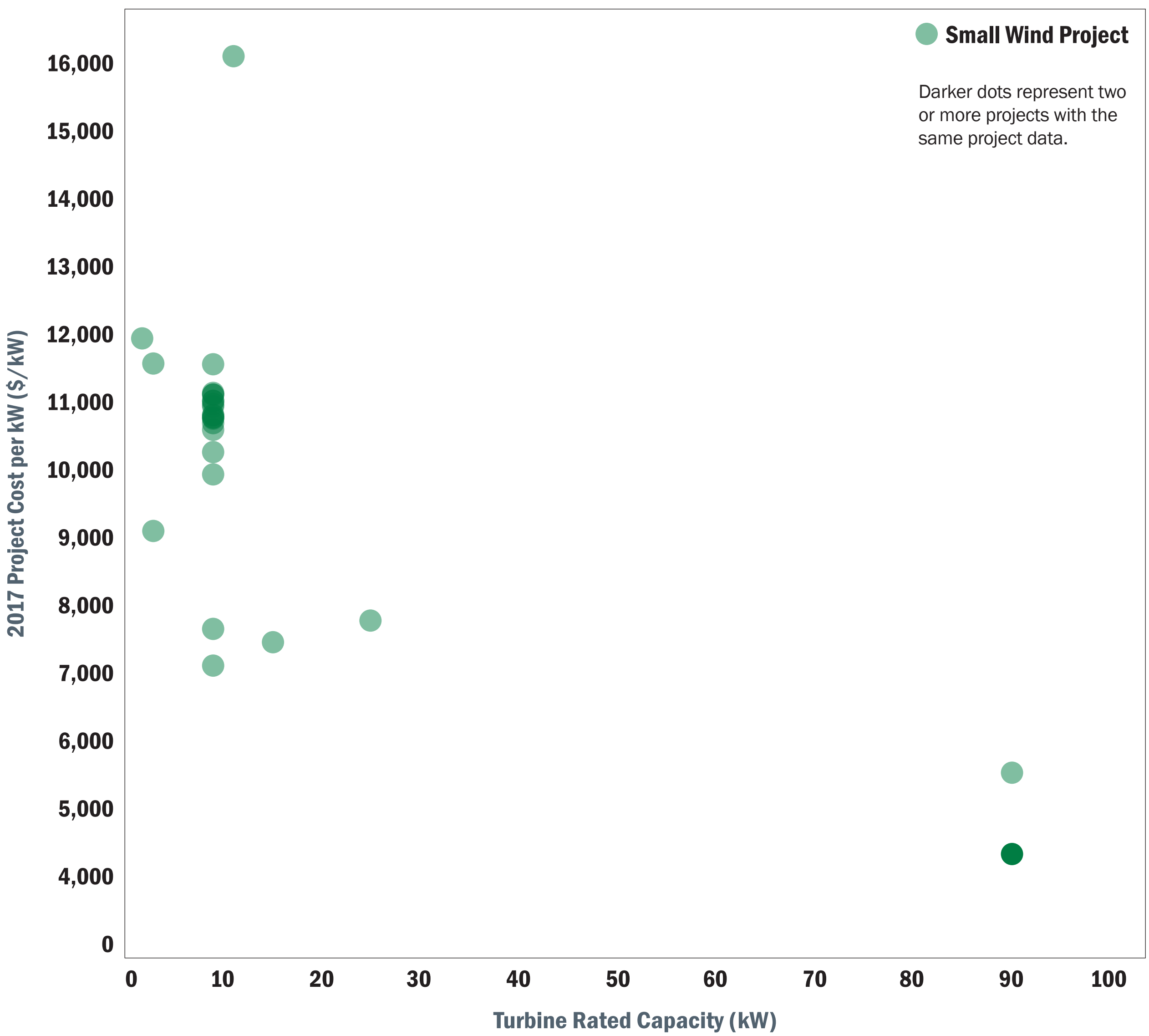


Figure 9. 2017 small wind project installed costs

[19] In past years, PNNL has presented small wind capacity-weighted average installed costs in this report. *Benchmarking U.S. Small Wind Costs* (Orrell and Poehlman 2017) used an arithmetic mean approach to calculate average costs, so the market report follows that approach for consistency and comparison. In addition, the small wind benchmarked

is available. Because of that, and because there are no turbines manufactured in certain sizes in the market, there is a gap in the figure's displayed costs. In 2016, the average small wind installed project cost was $9,777/kW based on 57 turbines totaling 1.2 MW of rated capacity across 10 states.

In September 2017, *Benchmarking U.S. Small Wind Costs* (Orrell and Poehlman 2017) found average installed small wind costs to be $11,953/kW for small wind systems up through 20 kW and $7,389/kW for small wind systems sized 21–100 kW, for an overall average of $10,847/kW in 2016 dollars.[20] Without adjusting for inflation and noting that some of the 2016 and 2017 projects are also represented in the benchmark dataset, the 2016 and 2017 average project costs are similar to the benchmark average project costs.

In past years, PNNL has asked small wind turbine manufacturers to report the average, or typical, installed cost of each of its turbine models sold in the United States. With the Distributed Wind Taxonomy now established, PNNL asked small wind manufacturers instead to report turbine system equipment and tower cost of goods sold along with the associated warranty costs and overhead and profit values. With limited responses thus far, this aspect of the taxonomy, different than total small wind installed costs, will be explored in future reports. Figure 9 reflects the total installed costs reported by installers and state and federal agencies.

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

For projects using turbines greater than 100 kW installed in the United States in 2017, installed project cost information was available for seven projects across five states, which used 20 turbines totaling 46.1 MW. The average per kW cost of these projects is $3,006/kW. The average cost for 2016 projects was $3,910/kW.

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

Related to this point, the decline in the 2017 average from 2016 is driven by a 30-MW project portfolio in Iowa that is actually six different sites, connected behind different substations to provide power to ethanol and biodiesel facilities on those local distribution grids. Typically, distributed wind projects 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. As a result, distributed wind projects using turbines greater than 100 kW typically have higher costs per kW compared to wind farms.[21] Manufacturers may also charge more for a single turbine order than for a bulk turbine purchase. However, this 30-MW multi-site project did likely benefit from economies of scale and a bulk turbine purchase, driving down its installed cost and the 2017 average installed cost.

5.3 Operation and Maintenance Costs

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

For a large distributed wind project, operation and maintenance costs of the turbine system are part of the project's total operating expenses. For the levelized cost of energy calculations in this report (see Section 7.0), the estimated annual total operating expense for projects using turbines greater than 100 kW is $50/kW/year based on data and analysis presented in the *2017 Wind Technologies Market Report* (Wiser and Bolinger 2018).

[20] The benchmark average costs are based on 70 projects built from 2012 through 2017 across 16 states, using 10 turbine models representing 1.5 MW in rated capacity.

[21] In 2017, the capacity-weighted average installed project cost for all projects using wind turbines greater than 100 kW was roughly $1,610/kW (Wiser and Bolinger 2018).

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

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

Figure 10 presents average and site-specific costs for scheduled maintenance site visits for a sample of small wind projects. This figure includes data collected for this report and for Orrell and Poehlman (2017), which was the first attempt to standardize how maintenance site-visit costs are tracked. Costs are broken out into average labor costs; average travel costs; and average consumables, parts, and other miscellaneous costs. The average scheduled maintenance cost per visit is about $37/kW.

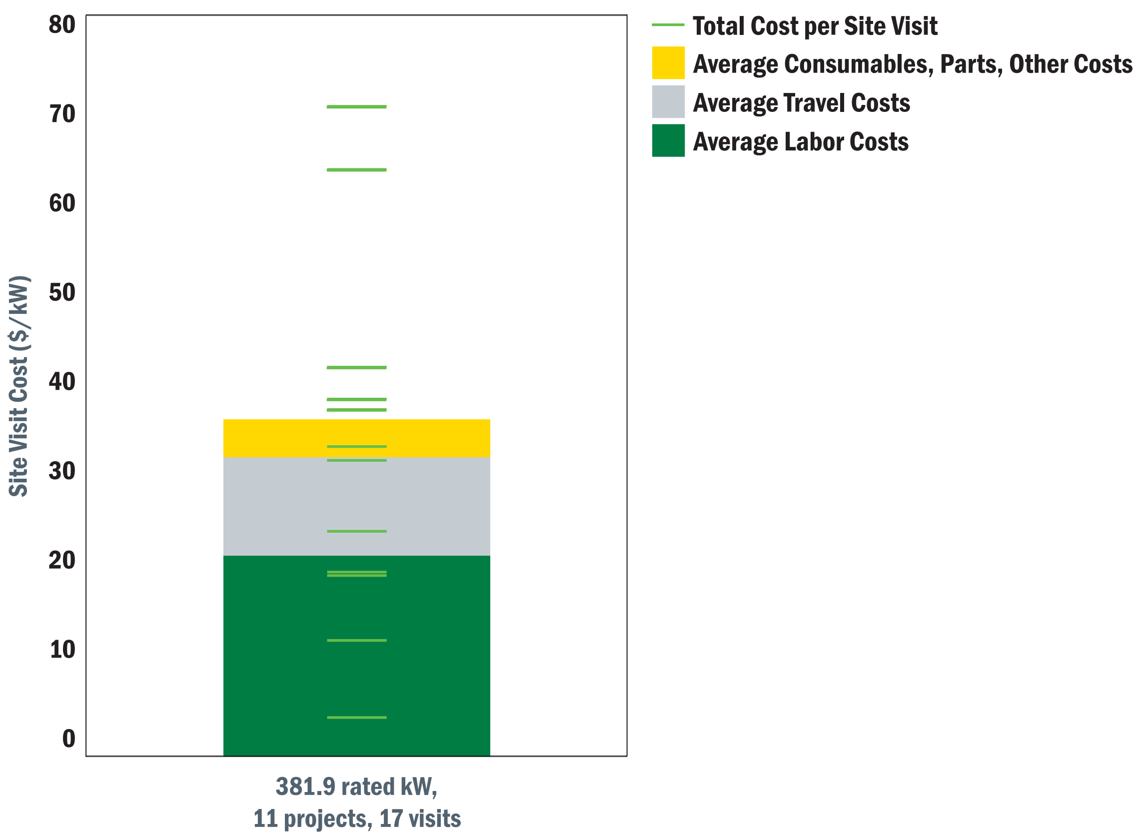


Figure 10. Small wind scheduled maintenance costs per site visit

In past years, installers have reported to PNNL average annual maintenance costs for the turbine models they service. While the $37/kW value represents an average scheduled maintenance site visit cost, it is very close to the average annual small wind maintenance costs reported by installers once converted to a per kW basis. Depending on turbine size, reported annual maintenance costs on a per kW basis range from $22 to $70 per kW (Orrell et al. 2017). As a result, $37/kW is used as the small wind O&M cost proxy in the levelized cost of energy calculations in Section 7.0.

6 Performance

A wind project's capacity factor is one way to measure the project's performance. The capacity factor is a project's actual annual energy production divided by its annual potential energy production if it were possible for the wind turbine to operate continuously at its full capacity.[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. The capacity factors are the average of three consecutive yearly capacity factors. To be included in the capacity factor analysis, projects needed to have three consecutive years of reported performance data and a known rated, or reference, capacity.

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

6.1 Capacity Factors

Figure 11 presents the calculated small wind capacity factors, based on the average of the first three years of reported generation for each project, from the combined NYSERDA and USDA REAP datasets, and rated turbine capacity. Figure 12 presents the three-year average capacity factors for the projects using turbines greater than 100 kW, based on their EIA-reported annual generation values in 2014, 2015, and 2016 (the most current, consecutive year data available from EIA) and the total project capacity based on turbine nominal capacity.

The three-year average capacity factor for large-scale wind turbines in distributed applications is 32%. The three-year average capacity factor for projects using mid-size turbines is 20%. The three-year average capacity factor for small wind is 16%.

The capacity factors shown in Figure 11 and Figure 12 represent a wide variety of projects. The USDA REAP dataset includes 19 small wind projects (totaling 505 kW in rated capacity) and 11 large-scale wind projects (totaling 18.7 MW) that were awarded grants in 2009 through 2014 in seven different states. After a grant is awarded, the 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 68 small wind projects (totaling 1.26 MW in rated capacity) and 3 mid-size turbine projects (825 kW) installed in New York State from 2010 through 2015. After installation, rebate recipients are required to submit performance reports at least twice per year for two years. Because of these NYSERDA and USDA REAP reporting arrangements, the analysis reflects those projects' first three years of operation.

The wide range of small wind capacity factors, from 2% to 36%, reflects the assessment and siting challenges for small wind described in the next section. The capacity factors for the 8.9-kW rated capacity turbines only range from 7% to 29%. The same turbine model sited in different locations can achieve very different capacity factors. In addition, low turbine availability, as a result of a turbine not operating for extended periods due to mechanical problems, can lower the turbine's overall annual capacity factor. Poor measuring and reporting of energy production may also be a factor.

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

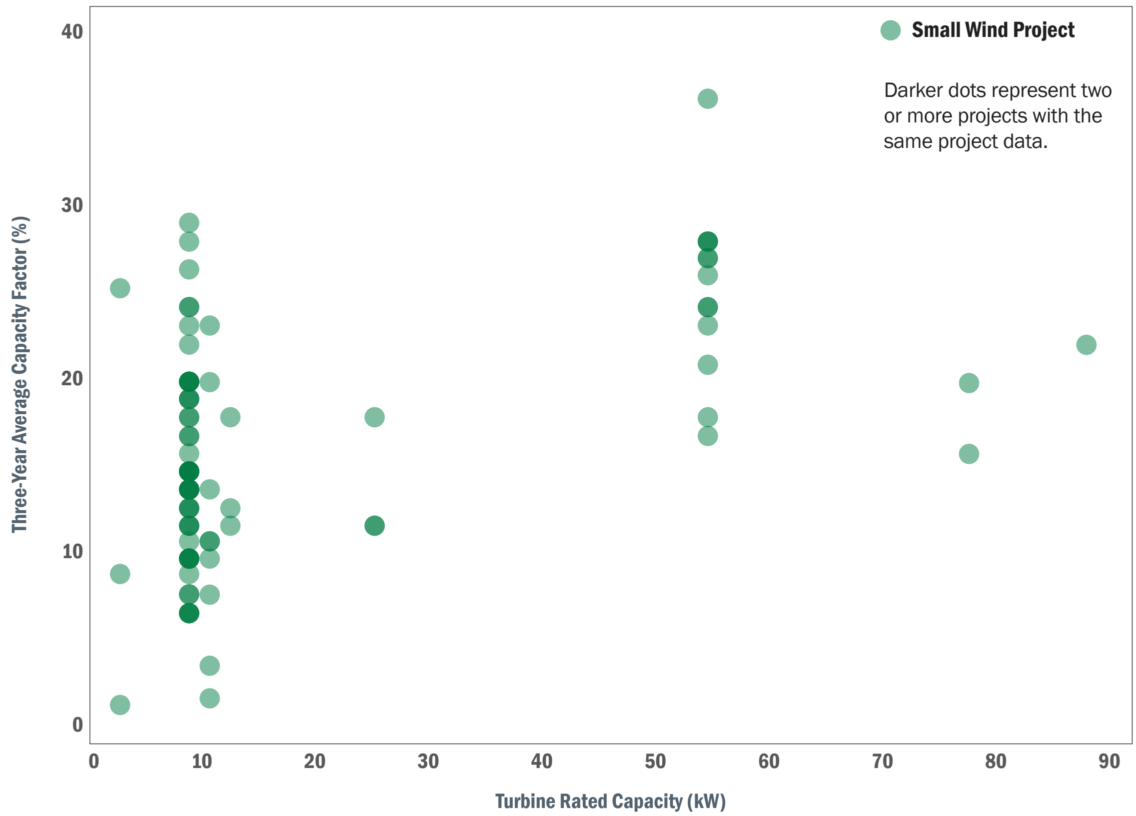


Figure 11. Small wind capacity factors

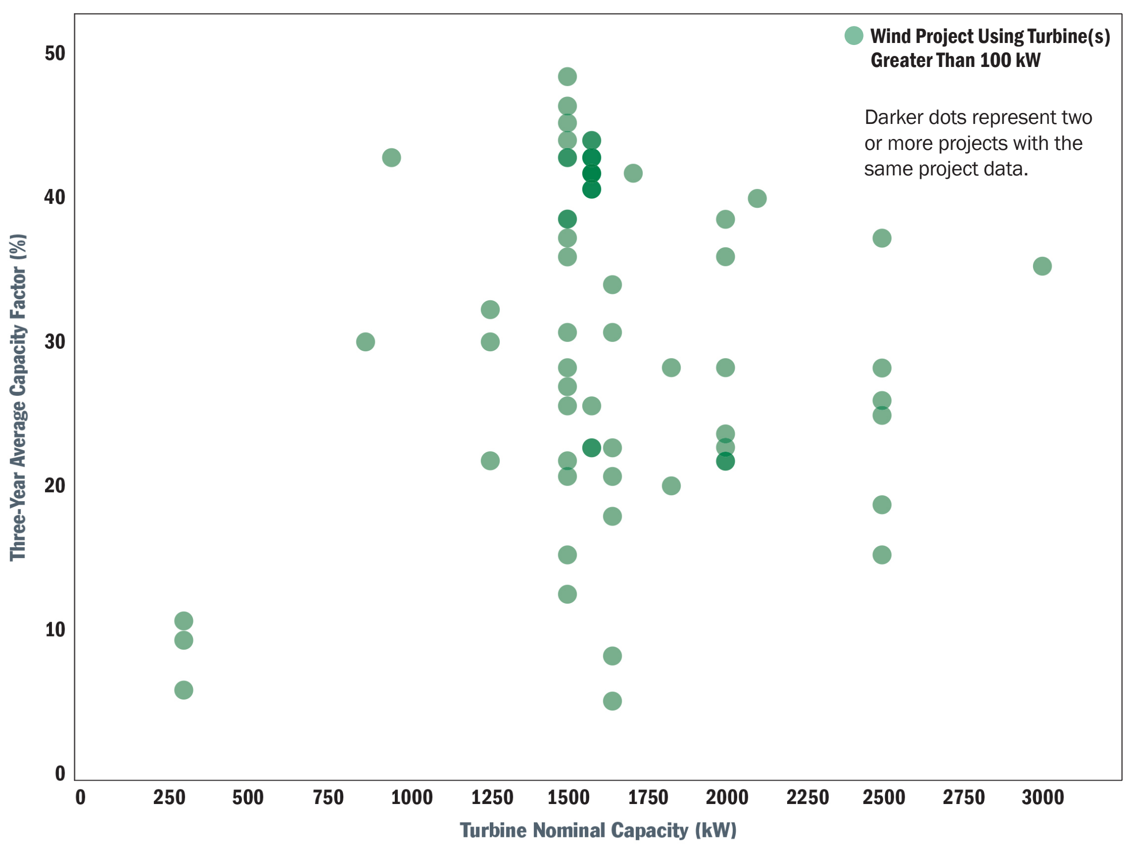


Figure 12. Capacity factors for projects using turbines greater than 100 kW

Wind projects with a total size of at least 1 MW are required to report net annual energy generation to the EIA in EIA-923 and EIA-860 reports (EIA 2018). From these records, 52 distributed wind projects, across 20 states, totaling 226 MW in capacity were analyzed.[23]

The average capacity factor in 2017 for all U.S. wind projects using turbines greater than 100 kW built from 2004 to 2011 was 31.5% (Wiser and Bolinger 2018), comparable to this report dataset's average of 32% and installation time frame of 2003 to 2013. However, the projects in Figure 12 also exhibit a wide range of capacity factors, from 6% to 49%. While the analysis presents a three-year average capacity factor based on generation values for 2014, 2015, and 2016, these projects were installed from 2003 to 2015. This snapshot in time could account for some of the variation, but siting and turbine availability issues may also play roles in large-scale distributed wind project performance as well. Nonetheless, the large-scale turbine project three-year average capacity factor is higher than that of small wind because large-scale turbine projects are more likely to have had a thorough wind resource assessment as part of the siting process to achieve optimal energy generation, and undergo routine maintenance to maintain high levels of reliability.

6.2 Actual Project Performance

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, as well as access to financing.

In the 2016 Distributed Wind Market Report, the performance analyses only considered the first year, or a single year, of projects' operation. Some distributed wind systems may experience debugging issues in their first year of operation (e.g., fine tuning the controller and fixing manufacturer defects), which means energy generation amounts in later years could be more representative of typical performance. There could be wind resource variability from year to year as well. This year's report compares the projects' predicted annual generation values against the projects' three-year average annual generation values based on three consecutive years of operation to account for inter-annual variability.

PNNL calculated each project's three-year average generation value and compared that to the project's projected generation value to establish what percent of projected production each project achieved. Table 4 presents the average of those percentages for different turbine size categories—small certified turbines, small non-certified turbines, mid-size turbines, and large turbines.

Table 4. Actual performance as a percentage of projected performance by turbine size

Turbine Size	Average Percent of Projected Production (%)	Number of Projects
Small Certified	92	66
Small Non-Certified	62	76
Mid-Size	70	3
Large	134	11

While Table 4 presents averages by turbine size, the full range of projected production values achieved ranges from as low as 1% to as high as 261%. For the distributed wind projects with very high overperformance values, the calculated capacity factors are physically possible, meaning the generation prediction was severely underestimated, or perhaps the wind resource in those years was significantly better than originally estimated.

In this sample of 156 projects, distributed wind projects using large-scale turbines generally achieved higher generation values than predicted, while small and mid-size turbines generally achieved lower generation values than predicted. The certified small wind turbines do exhibit a higher average of percent of projected production (92%) than the non-certified small wind turbines (62%). This difference is likely a result of many factors, as described below, and cannot be attributed solely to the turbine technology.

[23] 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.

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

One of the key challenges identified by stakeholders in the distributed wind industry is lack of access to wind resource data to accurately estimate a site's wind resource, especially for small wind projects. NREL has made available new WIND Toolkit data through the Wind Prospector tool[24] (NREL 2018). The available data includes hourly data at several heights relevant to distributed wind, such as 10 m, 40 m, and 60 m for the continental United States. Wind Prospector added GIS layers for average air pressure at ground level and wind speed, wind direction, and temperature at a height of 40 m. Before the end of 2018, the hourly time series data will be available to download for all hub heights and parameters in Wind Prospector and NREL's System Advisor Model.

[24] NREL's Wind Prospector tool: https://maps.nrel.gov/wind-prospector/

7 Levelized Cost of Energy

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

The energy production value used in each LCOE calculation is the project's three-year annual energy generation average from the USDA REAP, NYSERDA, and EIA datasets. The LCOE calculations also use the projects' installed costs, incentive award values, and estimated O&M costs. All costs are in 2017 dollars. The LCOE analysis is limited to projects for which complete information is available.

7.1 Levelized Costs of Energy by Turbine Size Class

Figure 13 presents the calculated small wind LCOEs from the NYSERDA and USDA REAP datasets. Figure 14 presents the calculated LCOEs for the projects using turbines greater than 100 kW (which includes both mid-size and large-scale turbines) from the three combined datasets.

The small wind average LCOE after incentives was 23¢/kWh (from 84 projects totaling 1.64 MW in rated capacity). The mid-size turbine project average LCOE after incentives was 28¢/kWh (from 4 projects totaling 5 MW). The large-scale turbine project average LCOE after incentives, was 4¢/kWh (from 32 projects totaling 114 MW).

If a project received a NYSERDA, REAP, and/or Section 1603 incentive, the installed capital cost used to calculate LCOE for that project was reduced by the total incentive award amount.[25] Rebates and grants reduce the upfront cost for the wind turbine owner significantly and, thus, reduces the LCOE for the owner as well. Incentives reduced the small wind LCOEs in this sample by an average of 41% and the mid-size and large turbine projects by an average of 18%. Without the incentives, small wind LCOEs range from 11 to 103¢/kWh and LCOEs for projects using turbines greater than 100 kW range from 2.8 to 51¢/kWh.

With these incentives, some of the distributed wind projects are cost competitive with retail electric rates. Behind-the-meter distributed wind projects displace electricity purchased at retail rates. According to the EIA, average residential retail electric rates, which small wind turbines are most likely to displace, range from 9.7¢ to 22¢/kWh in the continental United States. Average commercial rates, which mid-size and large-scale turbines could displace, range from 7.6¢ to 17¢/kWh (EIA 2018b). Hawaii, Alaska, Puerto Rico, the USVI, and Guam have higher rates, making distributed wind more cost competitive in those areas.

7.2 Levelized Costs of Energy and Capacity Factors

The relationship between calculated LCOEs after incentives and capacity factors is shown in Figure 15. In general, the higher the capacity factor, the lower the LCOE. Higher capacity factors, which in turn can reduce LCOEs, can be achieved by better siting, which can help increase energy production, and better turbine operations (i.e., higher turbine availabilities).

[25] NYSERDA rebates cover up to 50% of the project cost (via an incremental performance-based incentive). USDA REAP grants cover up to 25% of eligible project costs, or a maximum of $500,000. Section 1603 cash grants cover up to 30% of eligible project costs. For the small wind projects, three projects had a combination of REAP, NYSERDA, and/or Section 1603 grants. One project had a REAP and a Section 1603 grant, and two projects had REAP and NYSERDA grants. The remaining projects had either only a REAP or only a NYSERDA grant. For the distributed wind projects that use turbines greater than 100 kW, three projects received only a NYSERDA grant, four projects received only a USDA REAP grant, 19 projects received only a Section 1603 grant, and 10 projects received both a USDA REAP grant and a Section 1603 grant.

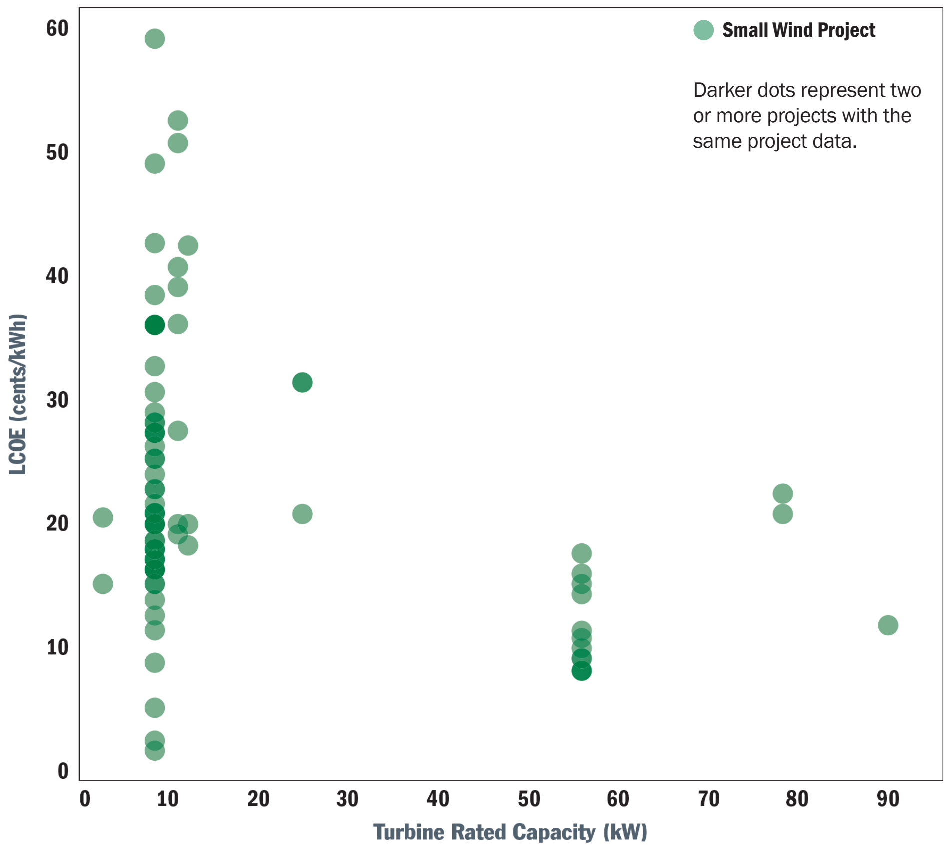


Figure 13. Levelized costs of energy (after incentives) for selected small wind projects

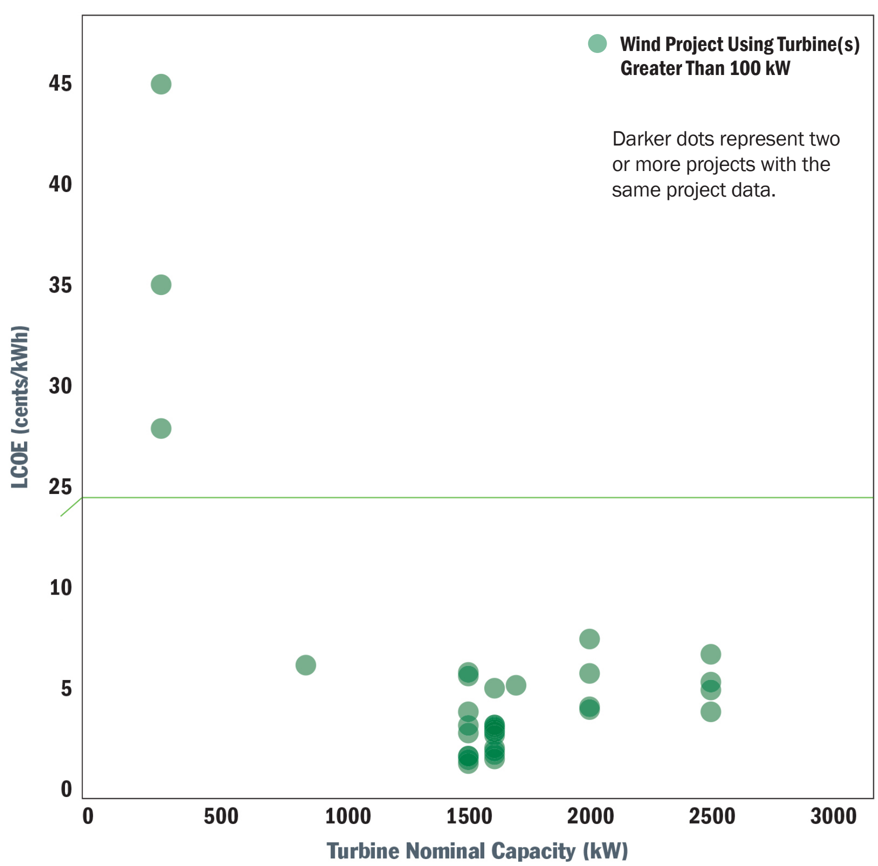


Figure 14. Levelized costs of energy (after incentives) for selected projects using turbines greater than 100 kW

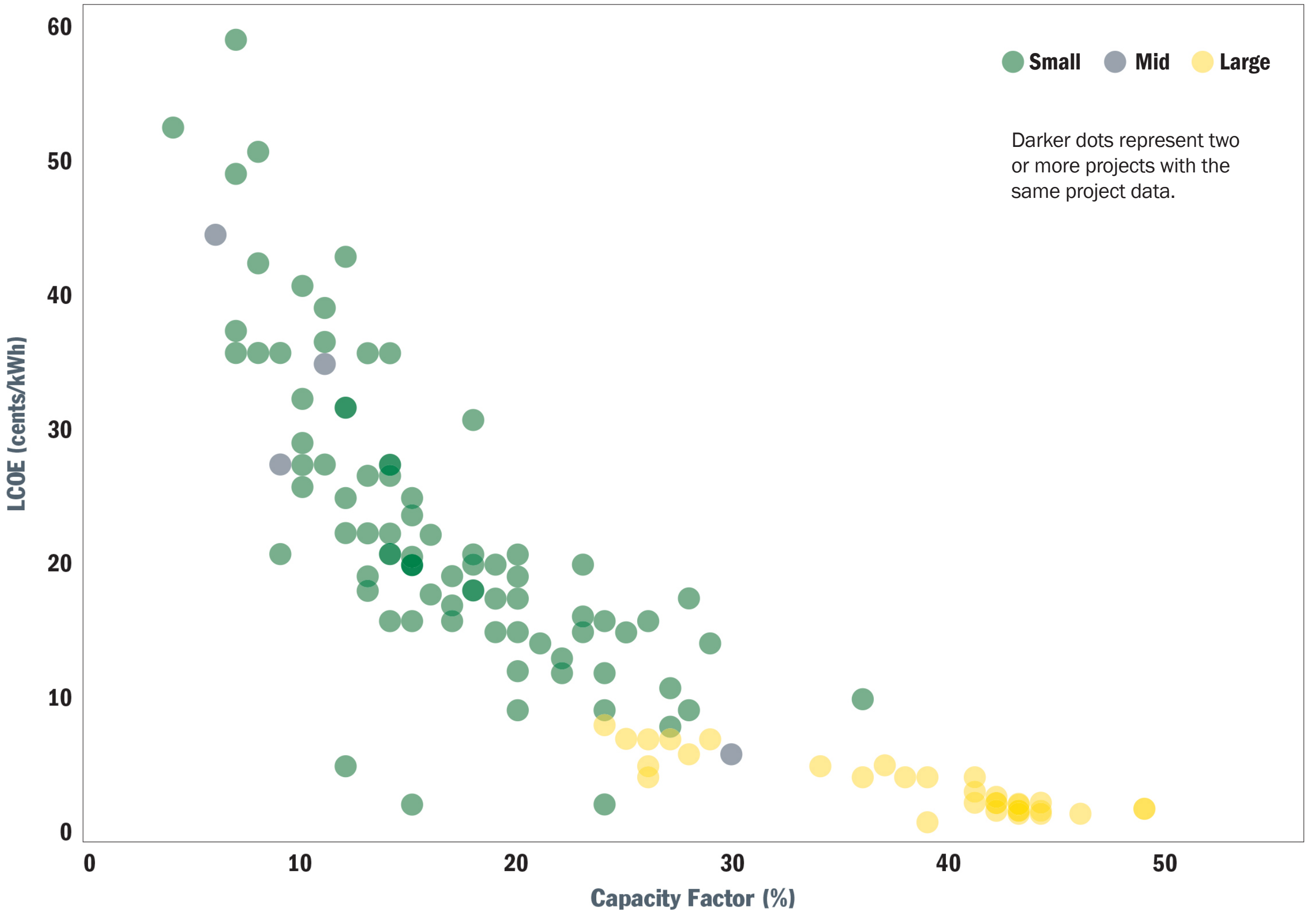


Figure 15. Levelized costs of energy (after incentives) and capacity factors

8 Distributed Wind Markets

This section of the report looks at some of the details, such as customer types and tower types, for distributed wind sales and installations in 2017.

8.1 Customer Types

Customers install distributed wind systems for a variety of reasons: increased energy security, lower utility bills, mitigation of energy price volatility, or simply to generate clean, renewable energy. This report considers seven main customer types for distributed wind: 1) residential, 2) agricultural, 3) industrial, 4) commercial, 5) government, 6) institutional, and 7) utility. In past reports, utility was considered a type of institutional customer; however, as more utilities build and purchase power from distributed wind projects, separating utility from institutional is informative.

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

Figure 16 shows the breakdown of customer types by number of projects[26] and by capacity for 2017. The figure illustrates how a small number of utility projects using large-scale turbines accounts for the majority of distributed wind capacity installed in 2017, compared to the larger number of residential projects that represent a smaller percentage of the overall 2017 capacity.

8.2 On-Site Use and Local Loads

Of the documented distributed wind capacity installed in 2017, 80%, from 10 projects, was connected to distribution lines serving towns; biodiesel and ethanol facilities; or utility service areas in Iowa, Nebraska, and Rhode Island. The other 20% of capacity, from 62 different projects, served on-site loads, either as behind-the-meter (91%), remote net-meter (just less than 9%), or off-grid (less than 1%) applications across 18 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 96% of turbine units in 2017 distributed wind applications were deployed to charge batteries or power off-grid sites such as remote homes, oil and gas operations, telecommunications facilities, boats, rural water or electricity supply, or military sites. However, grid-tied wind turbines accounted for nearly 100% of the annual distributed wind capacity (in MW) for projects that were tracked in 2017.

[26] The capacity and number of projects represented here are based on PNNL's project dataset. Small wind turbine sales with project-specific records were added to the project dataset, but most of the 2017 small wind units sold (i.e., the off-grid turbine units) were not tracked at the project level.

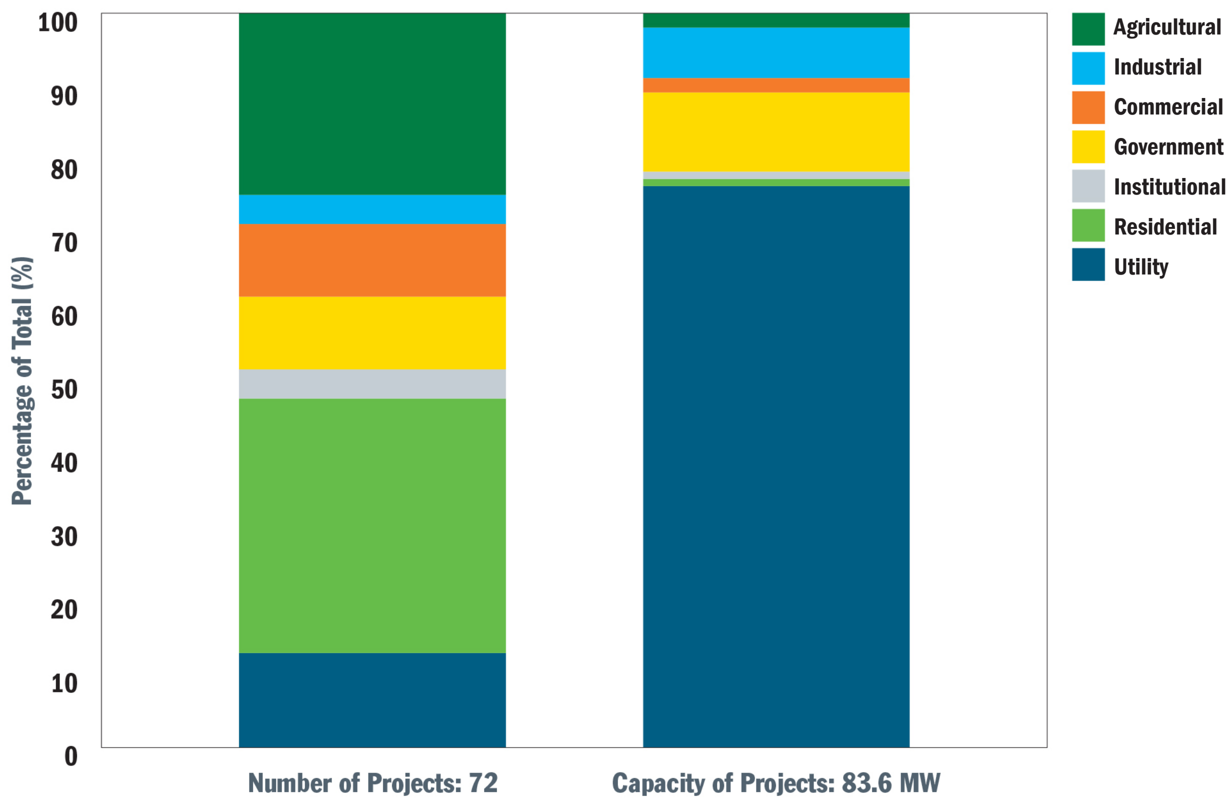


Figure 16. 2017 Distributed wind customer types by number and capacity of projects

8.4 Types of Wind Turbines

The overall number of wind turbine manufacturers supplying turbines for distributed wind projects has decreased significantly since 2012. This is a trend seen in both the United States and in the global market. For example, see the reduction in Chinese small wind manufacturers noted in Section 3.4.4. And as noted in Section 3.0, turbine manufacturer representation in the U.S. distributed wind market varies year to year, particularly foreign representation.

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

Some small wind manufacturers lack consistent sales from year to year. The single-year presence of a given manufacturer can have a significant impact on the overall small wind sales capacity (e.g., the 11- to 100 kW turbine category in 2015 compared to 2017). This yearly variation, segmented by small wind turbine size, is shown in Figure 17.[28]

Six out of the top 10 models of all wind turbines deployed in U.S. distributed applications in 2017 (on a unit basis) were from U.S.-based manufacturers.

[27] 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 federal ITC eligibility, a turbine must be new, where new is defined as having no more than 20% used parts. Therefore, some refurbished and retrofitted turbines do qualify for the federal ITC.

[28] The corresponding units for the annual deployed capacities are presented in the accompanying data file available at http://energy.gov/eere/wind/downloads/2017-distributed-wind-market-report

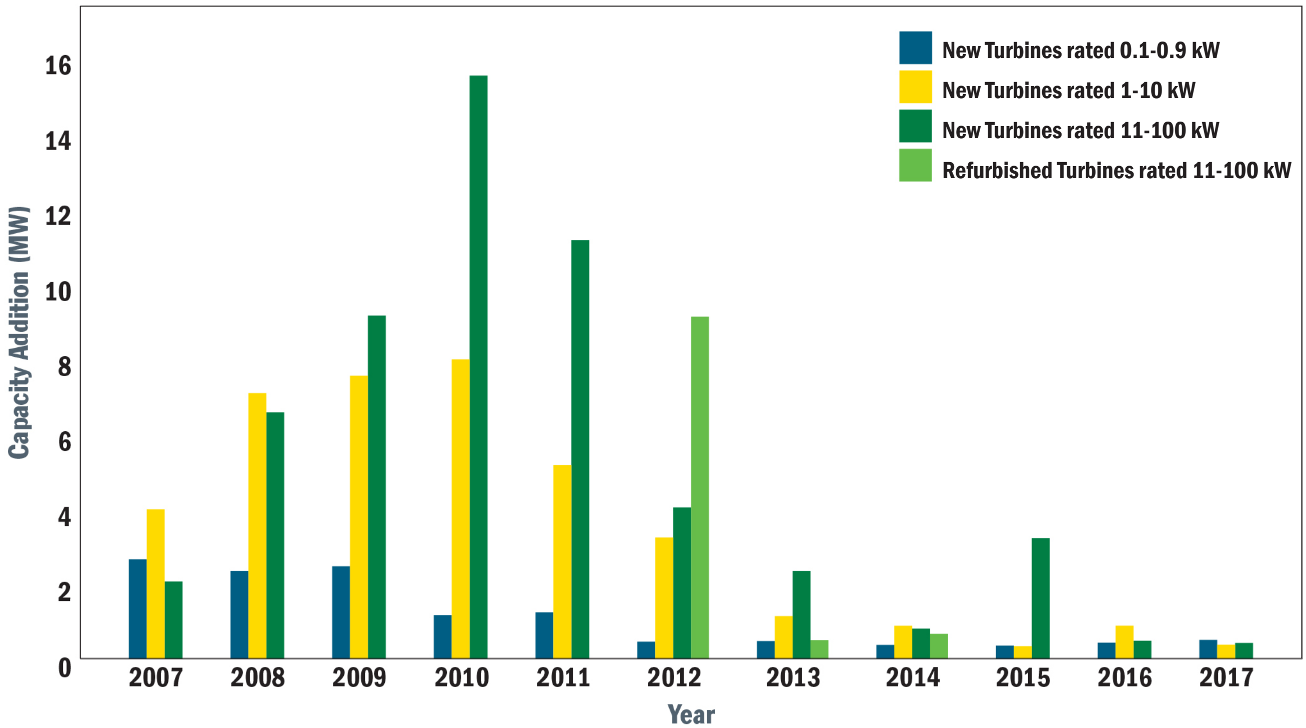


Figure 17. U.S. small wind sales capacity by turbine size

This report captures sales from the manufacturers who responded to the report's annual data request. While PNNL has an extensive data collection process (see Appendix B for details on the report's methodology), it is likely that some manufacturers were missed, particularly small wind vertical-axis wind turbine (VAWT) manufacturers. In this report, VAWT models represent about 2% of both U.S. small wind market units and capacity for 2017. This percentage is similar to past years in which VAWT representation has been about 1%–2% of U.S. small wind capacity.

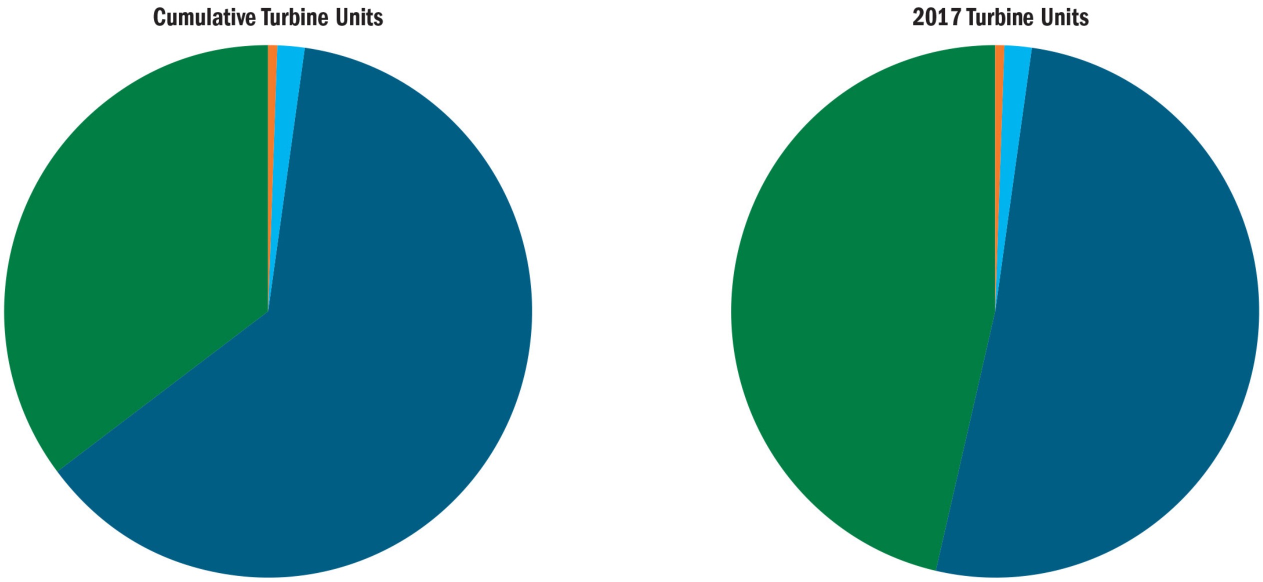
8.5 Types of Towers

Of the 62 different projects for which PNNL was able to collect tower type information, two tower types dominated: self-supporting lattice (48% of the 62 projects) and self-supporting monopole (40%). The remaining towers were tilt-up monopole (7%), guyed monopole (3%), and guyed lattice (2%). Self-supporting lattice and monopole towers were predominant for 2016 projects as well.

Reported hub heights for documented small wind projects ranged from 15 to 43 m, with 43 m being the most common. Hub heights for projects using turbines greater than 100 kW ranged from 65 to 87.5 m, with 80 m being the most common.

8.6 Distributed Wind Turbine Units

Wind turbines, of all sizes, that provide distributed energy account for 64% of the roughly 126,000 total wind turbines deployed in the United States (on a unit basis) since 2003 (Figure 18). However, because many of the turbines used in distributed applications are small, distributed wind accounts for just about 1% of all installed wind capacity in the United States. For context, Figure 18 also shows wind turbines greater than 100 kW installed in wind farms (i.e., projects that do not meet the definition of distributed wind).



Distributed Wind

190	Mid-Size Turbines	6
480	Large-Scale Turbines	36
80,475	Small Wind Turbines	3,269

Wind Farms

45,389	Wind Turbines > 100 kW	2,960

Figure 18. Cumulative (2003–2017) and 2017 wind farm and distributed wind turbine units

9 Small Wind Manufacturing

U.S.-made small wind turbines, sold in the United States or abroad, support various U.S. manufacturing and supply chain jobs. Small wind manufacturers and their supply chain vendors are located in at least 27 states, as shown in Figure 19. The supply chain vendors provide the mechanical, electrical, tower, and blade components for small wind turbines.

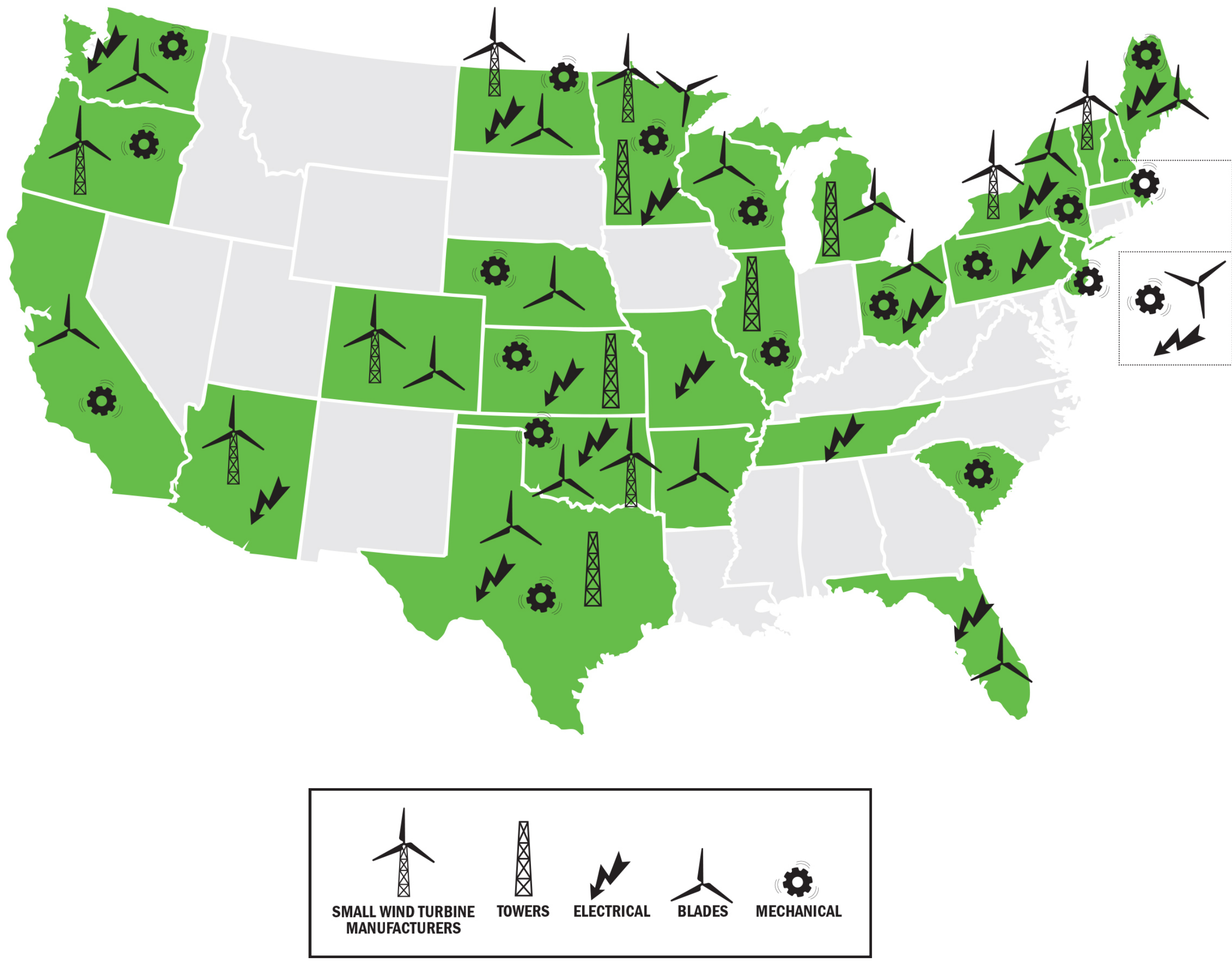


Figure 19. States with small wind manufacturing

10 Outlook

Distributed wind projects use turbines of all sizes and provide electricity for many different customer types, but deployment levels among and within the turbine size segments (i.e., small, mid-size, and large-scale) of the U.S. distributed wind market continue to vary, as they have year to year since 2012, the first year of this report. Market conditions and policies can affect the distributed wind market differently.

After a steady decline in small wind capacity deployment since a peak in 2012, the reinstatement of the Residential Renewable Energy Tax Credit could bolster the small wind market in the near term (DWEA 2018). On the other hand, this policy may have less impact on 1-kW and smaller wind turbines that typically provide electricity for remote, off-grid applications, as sales of these units have steadily increased since 2012. At the same time, the pending expirations of the federal PTC in 2019 and ITC in 2022 have likely driven the growth of large-scale turbine distributed wind projects. Renewable energy project developers are teaming with tax equity partners to develop many of those large-scale projects.

Even though they had few sales, an increased number of foreign-based small wind manufacturers have re-entered the U.S. market. Others have indicated interest in pursuing certification for their turbine models, which signals interest in expanded participation in the U.S. and global markets.

Industry stakeholders may consider the results of NREL's *Assessment of the Economic Potential of Distributed Wind in Colorado, Minnesota, and New York* (McCabe et al. 2018) when assessing market prospects. That report concluded the greatest economic potential for behind-the-meter distributed wind is for agricultural, commercial, and industrial end-use customers in low-density urban centers (e.g., industrial areas), suburban, and rural areas. In 2017, these types of projects were recorded for this report in the form of a 1.85-MW turbine for a vineyard in California, an additional 6-MW turbine for Whirlpool Corporation in Ohio, a second 100-kW turbine for a recycler in New York, three 100-kW turbines for hotels in Ohio, and several small wind turbines for New York farms.

Access to low-cost financing and reductions in capital costs were identified as factors in the NREL model that could increase distributed wind economic potential. Past editions of this Distributed Wind Market Report have described wind lease programs, first adopted by the solar PV industry, as an emerging market driver for distributed wind. Wind lease programs are one path to low-cost financing, but have yet to become widespread outside of New York State.

To counter the declining small wind market, small wind manufacturers are exploring different business expansion or realignment opportunities, such as energy storage and new turbine models like Bergey WindPower's Excel 15. Beyond that, large-scale turbine behind-the-meter projects and large projects on the distribution grid serving local loads are becoming more common, further growing and diversifying the nation's domestic energy industry.

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Appendix A: Wind Turbine Manufacturers and Suppliers

This report reflects 2017 sales and installations from the manufacturers and suppliers listed in Table A.1. Other companies that provided information, or only had sales outside of the United States, are recognized in the "Acknowledgments" section.

Table A.1. Wind Turbine Manfacturers and Suppliers

Manufacturer	Model Names	Headquarters
Small Wind Turbines (up through 100 kW)		
APRS World, LLC	WT10, WT14	Minnesota
Bergey WindPower	XL.1, Excel 6, Excel 10	Oklahoma
Britwind Limited	R9000	United Kingdom
C&F Green Energy	CF 15	Ireland
Dakota Turbines	DT-30	North Dakota
Eocycle	E025	Canada
HI-VAWT Technology Corporation	DS300, DS700, DS3000	Taiwan
Northern Power Systems	NPS 100, NPS 60	Vermont
Primus Wind Power	AIR 30, AIR X Marine, AIR 40, AIR Breeze, AIR Silent X	Colorado
QED Wind Power	PHX20	Arizona
Xzeres Wind	442SR, Skystream 3.7	Oregon
Wind Turbines (greater than 100 kW in U.S. distributed wind projects)		
Aeronautica	54-750	United States
Free Breeze Inc.	Refurbished V47-660	Canada
GE Renewable Energy	1.85-82.5, 1.7-100, 1.7-103	United States
Goldwind	GW87/1500	China
HZ Windpower	H111-2000	China
Nordex USA	AW125/3000	Germany
VENSYS	VENSYS 82	Germany

Appendix B: Methodology

The Pacific Northwest National Laboratory (PNNL) team issued data requests to 350 distributed wind manufacturers, suppliers, developers, installers, operations and maintenance (O&M) providers, state and federal agencies, utilities, and other stakeholders. The team compiled responses and information from these data requests (with sources listed in the "Acknowledgments" section) to tabulate the deployed United States and exported distributed wind capacity and associated statistics as of the end of 2017. The detail with which the stakeholders responded to the data requests varied, thus the team included sample sizes and qualifications with certain analysis presentations as needed.

A project dataset was created to capture all known projects installed in 2017. 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 projects on a per-project basis to determine if they met the U.S. Department of Energy's definition of distributed wind and therefore should be included in the distributed wind project dataset. For projects using small wind turbines (up through 100 kW), project records were obtained directly from manufacturers and suppliers, O&M providers, utilities, and agencies through e-mail, phone interviews, or both.

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

All records were compiled in the project dataset with a row for each 2017 project reported. Sales and installation reports from manufacturers, dealers, and developers were cross-referenced with records provided by agencies and installers to identify and combine information from duplicate records. Notes were made in instances of conflicting information (e.g., incentive award amounts, installed costs, and installation dates) as to which sources were used. Small wind turbine sales with project-specific records were added to the project dataset; however, most of the 2017 small wind units sold were not tracked at the project level.

The PNNL team also reviewed and cross-checked wind project listings published by Open Energy Information, Federal Aviation Administration, U.S. Geological Survey, U.S. Energy Information Administration, U.S. Environmental Protection Agency, and other sources. Identified projects not already in the AWEA records or reported by manufacturers or agencies were verified and added to the 2017 project dataset. Projects reported for 2017 were cross-checked against previous records to avoid double counting.

For small wind turbines, this study reports capacity and unit figures for the same calendar year as the reported sales by the manufacturers and suppliers for the purpose of tallying annual deployed capacity. However, some installations occur after the calendar year that the wind turbines were sold. U.S. sales presence is defined as manufacturers and suppliers documenting at least one sale in the United States in 2017.

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

The 2017 Distributed Wind Market Report is the DOE's sixth annual report. Project records from this, and past years, have been consolidated to produce a master project dataset.[29] When known, decommissioned turbines are removed from the dataset, but the cumulative figures principally represent annual capacity additions, rather than confirmed operating installations. Capacity allocations by state by year therefore may differ slightly from report to report.

Incentive payments and reports can lag behind or predate sales reports. This report tallies and reports incentive payments for the year in which they were granted, regardless of the time of installation, using the best information available at the time of publication. Projects that receive U.S. Department of Agriculture Rural Energy for America Program grants are recorded in the year the grant is awarded, although they may not be installed for up to two years after the grant. Project records in the master project dataset are updated accordingly when new information is available.

For the projects using turbines greater than 100 kW, the PNNL team used a variety of public (as listed in the "Acknowledgments" section) and a few private sources of data to compile the installed costs. The PNNL team and the Lawrence Berkeley National Laboratory team, authors of the annual Wind Technologies Market Report, share and cross-reference installed cost data for distributed wind projects. In some instances, installed cost figures are estimated based on reported incentive values.

In past reports, PNNL has relied on small wind manufacturer estimates of typical installed costs for their turbine models to estimate the investment values of small wind domestic sales and exports. These reported costs have consistently been lower than the total project-specific costs reported by installers and developers. With the Distributed Wind Taxonomy now established, PNNL will now ask small wind manufacturers to report turbine system equipment and tower cost of goods sold along with the associated warranty costs and overhead and profit values. As a result, PNNL estimated the 2017 small wind investment values using all the reported installed cost data available to the team from installers, agencies, manufacturers (whose turbines are not tracked on a project-level basis), and PNNL's Benchmarking U.S. Small Wind Costs report.

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

Table B.1. Turbine Models in Small Wind Dataset

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

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