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Distributed Wind Market Report: 2023 Edition

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List of Acronyms

ACP	American Clean Power Association
ANSI	American National Standards Institute
AWEA	American Wind Energy Association
DOE	U.S. Department of Energy
EIA	U.S. Energy Information Administration
FAA	Federal Aviation Administration
FIT	feed-in tariff
GE	General Electric
GW	gigawatt(s)
ICC–SWCC	International Code Council–-Small Wind Certification Council
IEC	International Electrotechnical Commission
IRA	Inflation Reduction Act
IRS	U.S. Internal Revenue Service
ITAC	Interstate Turbine Advisory Council
ITC	investment tax credit
kW	kilowatt(s)
kWh	kilowatt-hour(s)
LCOE	levelized cost of energy
MW	megawatt(s)
NPS	Northern Power Systems
NREL	National Renewable Energy Laboratory
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
PNNL	Pacific Northwest National Laboratory
PTC	production tax credit
PV	photovoltaic
REAP	Rural Energy for America Program
SGIP	Self-Generation Incentive Program
USDA	U.S. Department of Agriculture
WETO	U.S. Department of Energy's Wind Energy Technologies Office

Executive Summary

The annual Distributed Wind Market Report provides stakeholders with market statistics and analysis along with insights into market trends and characteristics for wind technologies used as distributed energy resources. This report presents the distributed wind market from 2003 through 2022. Key findings with respect to installed capacity, deployment trends, customer types, incentives, policies, installed costs and performance, and the future outlook are presented below.

Installed Capacity

Cumulative U.S. distributed wind capacity installed from 2003 through 2022 now stands at 1,104 megawatts (MW) from over 90,000 wind turbines across all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, the Northern Mariana Islands, and Guam. Distributed wind turbines are connected at the distribution level of an electricity system, or in off-grid applications, to serve specific or local loads.

In 2022, 13 states added 29.5 MW of new distributed wind capacity from 1,755 turbine units representing $84 million in investment. This compares to 11.7 MW of deployed capacity across 15 states from 1,751 turbines representing $41 million in investment in 2021 and 21.9 MW in 11 states from 1,497 turbine units representing $44 million in investment in 2020.

Of the 29.5 MW installed in 2022, 27.2 MW came from distributed wind projects using large-scale turbines (greater than 1 MW in size). No capacity came from projects using midsize turbines (101 kilowatts [kW] to 1 MW in size) and 2.3 MW came from projects using small wind turbines (up through 100 kW in size).

The 27.2 MW from four projects using 10 turbines greater than 1 MW is an increase from 8.7 MW (three projects with five turbines) in 2021 and 20 MW (five projects with eight turbines) documented in 2020. Large-scale wind turbines continue to account for most of the distributed wind capacity additions. The annual deployed capacity using large-scale turbines fluctuates from year to year because these projects have longer project-development cycles than smaller distributed wind energy projects and large-scale turbine technology continues to increase in nameplate capacity. Over the last five years, the average turbine size of turbines greater than 100 kW in distributed wind projects increased from 2.2 MW to 2.7 MW.

There were no reported distributed wind projects in 2022 that used midsize turbines (101 kW to 1 MW in size). Projects using midsize turbines have regularly represented a small part of the distributed wind market. In 2021, a total of 1.2 MW of midsize capacity from three projects using four turbines was deployed representing $2 million of investment, compared to 0.28 MW from two single-turbine projects in 2020 representing $0.4 million of investment.

A total of 2.3 MW of small wind turbines (up through 100 kW in size) was deployed in the United States in 2022 from 1,745 turbine units, representing $14.6 million in investment. This is up from 1.8 MW from 1,742 turbine units and $9.2 million in investment in 2021, and 1.6 MW from 1,487 turbine units and $7.2 million in investment in 2020. All small wind manufacturers and suppliers who responded to the Pacific Northwest National Laboratory (PNNL) data request reported higher sales in 2022 than in 2021.

Iowa, California, and Nebraska led the United States in new distributed wind capacity additions because of two large projects in Iowa and one large project each in California and Nebraska that collectively represent 92% of the distributed wind capacity installed in 2022. ConEdison Development installed two 7.94-MW projects connected to load-serving distribution lines owned by Interstate Power & Light in Iowa. Foundation Windpower installed a 5.64-MW behind-the-meter project for Dole Fresh Vegetables, Inc. in California. And Bluestem Energy Solutions installed a 5.64-MW project connected to a load-serving distribution line owned by Southern Public Power District in Nebraska.

Minnesota added the most small wind capacity in 2022 with 327 kW. This can be attributed to Eocycle's continued push to sell its EOX-S16 turbine model to farmers in Minnesota to provide a decarbonization solution for the emissions-heavy agriculture industry.

Deployment Trends

General Electric (GE) Renewable Energy has been the only consistent U.S.-based manufacturer of large-scale turbines used in distributed wind projects over the past 10 years and was the only large-scale turbine provider for distributed wind projects in 2022.

Small wind repowers accounted for a reduced portion of new small wind capacity deployment in 2022 compared to previous years. Repowers are new turbines installed on existing towers and foundations to replace nonfunctioning turbines or to upgrade the technology. In 2022, small wind repowers represented just 8% of total installed small wind capacity, compared to 36% in 2021 and 79% in 2020.

In 2022, 90% of distributed wind projects were deployed to provide energy for on-site use and 10% of projects were interconnected to a distribution grid to provide energy for local use. Historically, while most of the distributed wind projects documented are interconnected for on-site use, they make up less of the total deployed distributed wind capacity. In 2022, the projects for on-site use accounted for 22% of the deployed distributed wind capacity while 78% of the capacity was from projects connected to the distribution grid.

Customer Types

In 2022, projects for agricultural customers accounted for 33% of the number of all projects installed. Residential and commercial customers each represented 26%, utility customers represented 10%, and industrial and institutional customers each represented just under 3% of installed projects.

Distributed wind deployed for utility customers represented the largest share of total distributed wind capacity installed in 2022, accounting for 78% of the documented capacity. Industrial customers represent the second largest percentage of distributed wind capacity installed in 2022, accounting for 20% of installed capacity. Three of the four projects using large-scale wind turbines were for utilities—the other was for an industrial customer. Distributed wind for agricultural, residential, commercial, institutional, and government customers each accounted for 1% or less of the distributed wind capacity installed in 2022.

Incentives and Policies

The Inflation Reduction Act (IRA) of 2022 enacted long-term incentives for distributed wind that will be available for at least the next decade. The IRA extends the Residential Renewable Energy Tax Credit applicable to small wind turbines through 2034. The IRA also extends the Business Energy Investment Tax Credit (ITC) through 2024. Starting in 2025, the current technology-specific ITCs and Production Tax Credit (PTC) options will be replaced with a technology-neutral ITC and PTC that will be available to all energy-generation technologies with zero or net-negative carbon emissions before beginning to phase out in 2032 or when U.S. power sector emissions have dropped by at least 75% compared with 2022 levels, whichever comes later. The extended and new tax credits have new provisions for additional, stackable bonus credits of 10 percentage points for the ITC and 10% for the PTC for locating facilities in "energy communities" or for meeting domestic content requirements. Further ITC bonuses up to 20 percentage points are available on a limited, competitive basis for wind or solar projects less than 5 MW (and from 2025 on for other clean energy) that are located in or benefit low-income communities or are located on tribal lands. The IRA also includes direct-pay provisions for non-tax paying entities that will enable access to the credits for organizations like municipal utilities and rural electric cooperatives.

The IRA also provides significant new loan and grant authority from which distributed wind could benefit. The U.S. Department of Agriculture's (USDA) Rural Energy for America Program (REAP) received a funding allocation of over $2 billion, with $303 million set aside for underutilized technologies and technical assistance. Wind is an eligible underutilized technology. The new IRA provisions for REAP also doubled the maximum allowable grant size from $500,000, or 25% of costs, to $1,000,000, or up to 50% of costs, for renewable energy projects.

Distributed wind projects across eight states received a total of $5 million in state-level PTCs and USDA REAP grants in 2022. This is roughly the same as the $5.2 million paid across eight states in 2021 and the $4.8 million paid across six states in 2020, although those past year totals include other incentive payments in addition to USDA REAP grants and state PTCs.

While at least 23 different small wind turbine models have been certified to the American Wind Energy Association (AWEA) 9.1-2009 standard or the International Electrotechnical Commission (IEC) 61400 standards since 2011, a total of nine small wind turbine models have current certifications as of June 2023. Small wind turbine manufacturers must renew certifications annually. Manufacturers may opt not to renew if they no longer want to participate in the U.S. market or if the company has discontinued operations. Small wind turbines must meet either of these standards to be eligible to receive the federal Business Energy ITC per the U.S. Internal Revenue Service.

The American Clean Power Association (ACP), the successor to AWEA, published its new American National Standards Institute (ANSI) consensus standard, ANSI/ACP 101-1-2021, in October 2022. The Distributed Wind Energy Association and the U.S. Department of Energy have recommended that the U.S. Internal Revenue Service recognize legacy certifications to AWEA 9.1-2009 new certifications to ANSI/ACP 101-1 going forward for small wind Business Energy ITC eligibility.

Installed Costs and Performance

The overall average capacity-weighted installed cost for new small wind projects from 2013 through 2022 was $10,670/kW. Small sample sizes for cost data in 2018, 2020, and 2022, along with high variance in distributed wind project costs, prevent clear identification of cost trends for small wind turbine installations over time.

The overall average capacity-weighted installed cost for projects using turbines greater than 100 kW for the period of 2013 through 2022 is $4,050/kW. The PNNL team documented four distributed wind projects using turbines greater than 100 kW for 2022 and only one of them has a reported installed cost, so no average cost was calculated for 2022.

The overall average capacity factor in 2022 for a sample of small wind projects was 15%. Observed capacity factors ranged from 1% to 37% for the sample of 101 turbines totaling 1.4 MW in rated capacity.

The overall average capacity factor in 2022 for a sample of distributed wind projects using turbines greater than 100 kW was 23%. Observed capacity factors ranged from 6% to 39%. The sample includes 27 distributed wind projects installed from 2005 to 2018, across 14 states, totaling 95 MW in combined capacity with turbine nominal capacities ranging from 600 kW to 3 MW.

A total of 60% of the distributed wind projects PNNL analyzed had higher capacity factors in 2022 than in 2021. This can largely be attributed to a stronger wind resource year in the Midwest and Northeast United States. Of the 122 distributed wind projects using turbines of all sizes that PNNL analyzed, a total of 73 had capacity factors in 2022 that exceeded their capacity factors in 2021 (with 25 of them in the Midwest and 20 in the Northeast). A total of 28 projects underperformed in 2022 relative to their capacity factors in 2021 and the remaining 21 projects performed similarly between the two years.

Future Outlook

With the passage of the IRA and associated long-term incentives for distributed wind, the outlook for future distributed wind deployment looks much improved. The National Renewable Energy Laboratory's *Distributed Wind Energy Futures Study* estimates distributed wind economic potential at 919 gigawatts (GW) for behind-the-meter installations and 474 GW for front-of-the-meter installations in a 2022 baseline scenario. Economic potential increases substantially to 1.7 TW for behind-the-meter applications and more than 4 TW for front-of-the-meter installations in a 2035 future scenario that includes reduced barriers to permitting and an extension of the federal ITC roughly equivalent to that provided under the IRA.

Table of Contents

List of Figures

List of Tables

1 Introduction

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

Distributed wind turbines are distributed energy resources connected at the distribution level of an electricity system, or in off-grid applications, to serve specific or local loads. Distributed wind installations can range from a less-than-1-kilowatt (kW)[1] off-grid wind turbine at a remote cabin or oil and gas platform, to a 15-kW wind turbine at a home or farm, to several multimegawatt wind turbines at a university campus, at a manufacturing facility, or connected to the distribution system of a local utility.

In most cases, individuals, businesses, and communities install distributed wind to offset retail power costs. However, other reasons consumers install distributed wind include to secure long-term power cost certainty, support grid operations and local loads, help meet decarbonization goals, and electrify remote locations and assets not connected to a centralized grid.

1.1 Purpose of Report

The Pacific Northwest National Laboratory (PNNL) team produces the annual Distributed Wind Market Report as part of DOE's Wind Energy Technologies Office (WETO) Distributed Wind Research Program. The program aims to enable wind technologies as distributed energy resources to contribute maximum economic and energy system benefits now and in the future.

To that end, the Distributed Wind Market Report contains analysis on distributed wind projects of all sizes. By providing a comprehensive overview of the distributed wind market, this report can help guide future investments and decisions by industry, utilities, federal and state agencies, and other interested parties. This report provides key information to help industry members understand and access market opportunities and inform distributed wind research and development needs.

1.2 Distributed Wind Applications

Distributed wind can be classified by where the turbine is installed relative to the local distribution grid (see Section 8.2). Grid-connected turbines are typically either behind-the-meter (to provide electricity for on-site use) or front-of-meter (to provide electricity for local use) installations.[2] A behind-the-meter wind turbine is one that is always connected to the local distribution grid behind a customer's utility meter—typically to offset all or some of the on-site energy needs. Behind-the-meter wind turbines displace retail electricity demand and can be net-metered to credit excess output flowing back onto the grid. A wind turbine connected to a distribution grid as a generation resource is considered a front-of-meter installation. Front-of-meter wind projects provide energy and grid support to the distribution system and help serve the interconnected local loads on the same distribution system.

A wind turbine can be off the grid in a remote location as a distributed energy source for on-site energy needs. An off-grid distributed wind turbine can be deployed with a battery or other form of energy storage because the wind turbine is not connected to a local distribution grid that could provide backup energy or accept excess energy. An off-grid wind turbine typically serves a single load, such as a remote telecommunications site or a cathodic protection system to prevent corrosion on an oil pipeline, and is not connected to any utility distribution grid.

[1] 1 gigawatt (GW) = 1,000 megawatts (MW); 1 MW = 1,000 kilowatts (kW); 1 kW = 1,000 watts (W)

[2] Grid-connected distributed wind turbines can be physically or virtually connected to the distribution grid or on the customer side of the meter. Virtual (or remote) net-metering allows a member to receive net-metering credit from a remote renewable energy project as if it were located behind the customer's own meter.

Distributed wind can also be part of a grid-connected microgrid or isolated grid. A microgrid is a group of interconnected loads and distributed energy resources within defined electrical boundaries that can operate in either a connected or disconnected (islanded) mode from the local distribution grid (Ton and Smith 2012). An isolated electrical grid system powers many loads and typically serves a whole community, such as a remote village, and is not connected to a larger grid system.

1.3 Wind Turbine Size Classifications

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

- Small wind turbines are up through 100 kW (in nominal, or nameplate, capacity)[3].
- Midsize wind turbines are 101 kW to 1 megawatt (MW).
- Large-scale wind turbines are greater than 1 MW.

For projects using turbines greater than 100 kW, the project's total nominal power capacity is used in this report's cost-per-kW analysis and related analyses. For small wind, this report uses the total rated power capacity of the project in the cost-per-kW analysis and related analyses, rather than nameplate capacity.[4] 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) Small Wind Turbine Performance and Safety Standard 9.1-2009 or the American National Standards Institute (ANSI)/American Clean Power Association (ACP) 101-1-2021 Small Wind Turbine Standard.[5] For uncertified small wind turbines, the power output at 11 m/s is assigned as the turbine's rated, or referenced, capacity.

The turbine manufacturers and models used in distributed wind projects recorded for 2022 are listed in Appendix A. Rated capacities for the small wind turbine models included in this report are listed in Appendix B.

1.4 Data-Collection, Categorization, and Analysis Methodologies

To collect data on distributed wind installations, sales, and related activities that occurred in calendar year 2022, the PNNL team issued data requests to small wind turbine manufacturers, suppliers,[6] developers, installers, and operations and maintenance (O&M) providers; distributed wind project developers; state and federal agencies; utilities; and trade associations. The PNNL team also reviewed data from other sources for distributed wind projects using turbines greater than 100 kW. This report includes data from past data requests and presents the distributed wind market from 2003 through 2022. In some cases, because of data availability and quality, analyses use different periods within that range.

The PNNL team created a project dataset to capture all projects installed in 2022 identified through the data-request and data-review process. That dataset has been consolidated with those created for past years to create a master project dataset that is available (with a free registration) on PNNL's Distributed Wind Data website.

The PNNL team regularly updates the master project dataset when new information becomes available. For example, when the PNNL team identifies projects that were installed in past years but were not previously recorded, the team adds those projects to the master project dataset. Those updates are then included in the

[3] The U.S. Internal Revenue Service (IRS) also defines small wind as up through 100 kW for the purpose of federal small wind ITC eligibility (see Section 4.1.2).
[4] The nominal, or nameplate, capacity of a wind turbine is what manufacturers use to describe, or name, their wind turbine models. In the case of small wind, the nameplate capacity can be significantly different from a turbine's rated capacity. As a result, rated capacities for small wind turbines are used in this report's per-kW analyses to provide a consistent baseline. For turbines greater than 100 kW, the turbine's nameplate capacity matches the turbine's pitch-regulated maximum power output, allowing the nameplate capacity to be the consistent baseline.
[5] Small wind turbine standards are discussed in Section 4.2.4.
[6] In relation to manufacturers, suppliers provide refurbished turbines.

current year report's figures and analyses. Further, the PNNL team marks turbines confirmed to be decommissioned in the dataset as such, but does not actively track decommissioning, so the team cannot guarantee that only operating projects are included in the project dataset. Consequently, the cumulative capacity amount presented in this report, and capacity allocations by state and by year, represents deployed capacity and may differ slightly from report to report. The master project dataset is used to make year-to-year comparisons; allocate capacity amounts across states; analyze installed costs; identify incentive funding levels; and characterize distributed wind customers, types of turbines and towers, and project applications.

The PNNL team also created a separate small wind sales dataset based on the sales reports provided by the manufacturers and suppliers listed in Appendix A.[7] 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 report details capacity figures for the same calendar year as sales reported by the manufacturers and suppliers to tally annual deployed capacity.

Many small wind turbine units sold are not tracked at the project level, such as off-grid turbine units sold by the manufacturer to distributors for resale to end users. As a result, the PNNL team is unable to include them in the master project dataset. Each year's reported annual deployed capacity is a combination of the small wind sales and the installed projects using turbines greater than 100 kW installed in that year.

Appendix B provides additional details about data-collection, categorization, and analysis methodologies.

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

2 U.S. Distributed Wind Deployment

From 2003 through 2022, over 90,000 wind turbines have been deployed in distributed applications across all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, the Northern Mariana Islands,[8] and Guam, totaling 1,104 MW in cumulative capacity, as shown in Figure 1.[9]

In 2022, 13 states added 29.5 MW of new distributed wind capacity from 1,755 turbine units representing $84 million in investment.[10] This is an increase from past years. A total of 11.7 MW of capacity was deployed across 15 states from 1,751 turbine units representing $41 million in investment in 2021. In 2020, 21.9 MW were deployed in 11 states from 1,497 turbine units representing $44 million in investment.

Figure 1. U.S. distributed wind capacity

2.1 Top States for Distributed Wind: Annual and Cumulative Capacity

New distributed wind projects were documented in 13 states (i.e., California, Iowa, Kansas, Michigan, Minnesota, Montana, Nebraska, New York, Ohio, Illinois, Virginia, Vermont, and Wisconsin) in 2022 and have been documented in all 50 states, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, the Northern Mariana Islands, and Guam since 2003, as shown in Figure 2.

[8] A distributed wind turbine installed in 2011 with American Recovery and Reinvestment Act funding was brought to PNNL's attention and added to PNNL's master project dataset in 2023.
[9] The data presented in the figures are provided in an accompanying data file available for download at https://energy.gov/windreport.
[10] All dollar values are nominal unless otherwise noted. Annual and cumulative capacity amounts are based on nameplate turbine-capacity sizes.

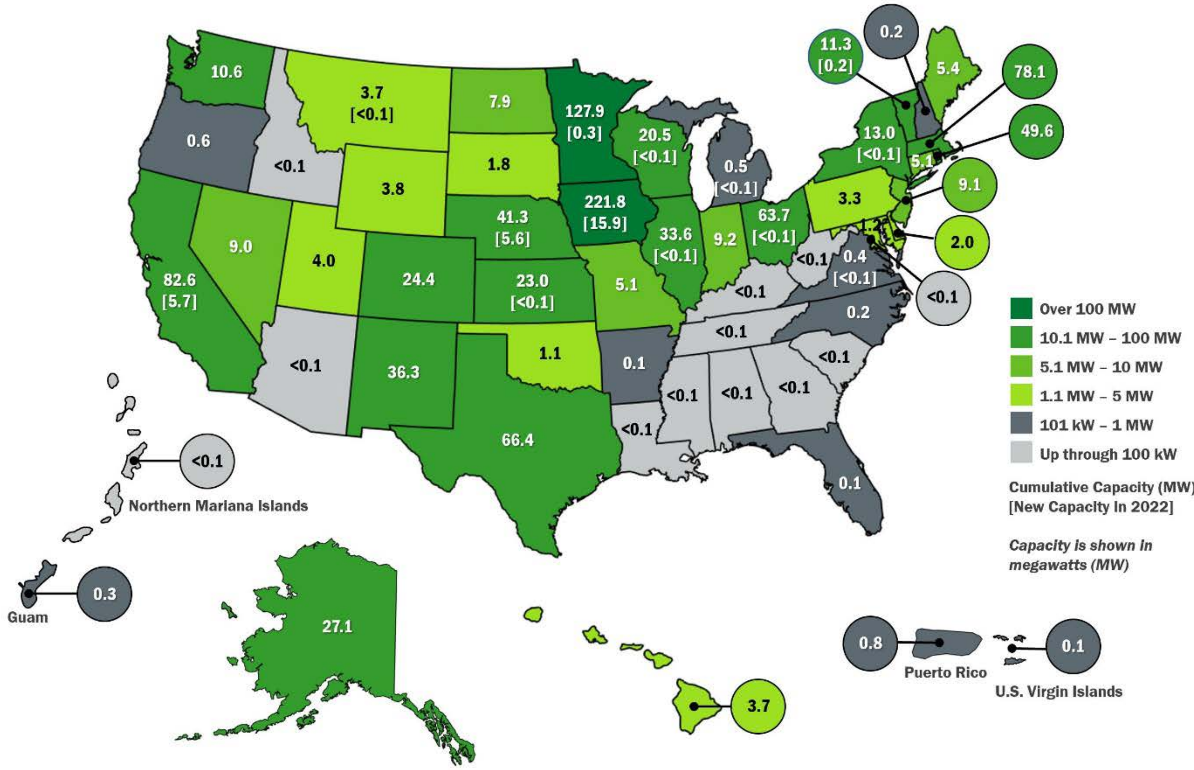

Figure 2. U.S. cumulative (2003–2022) capacity and capacity additions in 2022 for distributed wind by state

Iowa, California, and Nebraska led the United States in new distributed wind power capacity in 2022. This is because of two large projects in Iowa and one large project each in California and Nebraska. ConEdison Development installed two 7.94-MW projects connected to load-serving distribution lines owned by Interstate Power & Light in Iowa.[11] Foundation Windpower installed and operates a 5.64-MW behind-the-meter project for Dole Fresh Vegetables, Inc. in California. And Bluestem Energy Solutions installed and operates a 5.64-MW project connected to a load-serving distribution line owned by Southern Public Power District in Nebraska. These projects collectively represent 92% of the distributed wind capacity installed in 2022.

The concentration of a few projects using large-scale turbines in a few states can mainly be attributed to the project development cycles of a handful of developers. Because each company works almost exclusively in a single state or region rather than nationally, except for ConEdison Development,[12] annual distributed wind capacity additions can be concentrated in a few states. Project developers, namely Juhl Energy in Minnesota; One Energy Enterprises LLC (One Energy) in Ohio; Green Development, LLC in Rhode Island; Foundation Windpower in California; Optimum Renewables in Iowa; WES Engineering in Minnesota and Wisconsin; and Bluestem Energy Solutions in Nebraska, may not install new projects every year, as shown in Figure 3, because each project can take at least two to four years to develop (ACP 2022). The eight developers highlighted in Figure 3 have accounted for nearly 70% of the distributed wind capacity from projects using turbines greater than 100 kW each year since 2018. The “other” category in Figure 3 primarily includes project owners (e.g., universities and municipalities), other third-party developers with a less consistent presence, and unknown developers.

[11] One of these projects may have been installed, or partially installed, in 2021, but PNNL is counting both projects in 2022 because of incomplete data availability.
[12] PNNL has documented distributed wind projects installed by ConEdison Development in Minnesota, Massachusetts, and Iowa. The company was acquired by RWE, a European energy company, in 2022 (RWE 2022).

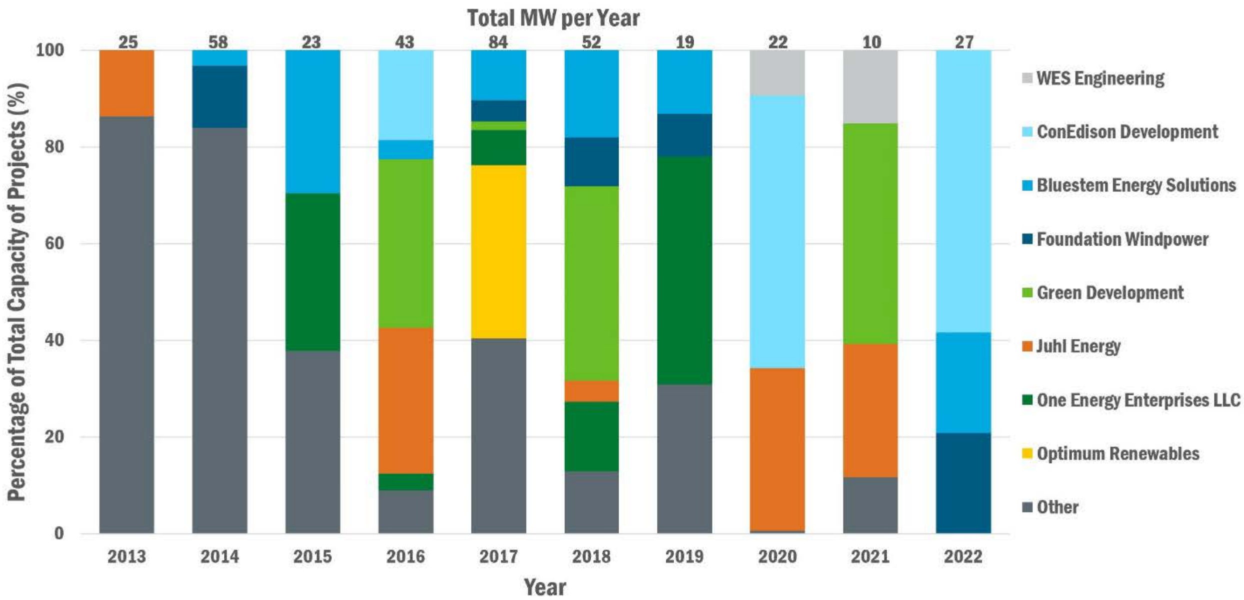

Figure 3. Project developers using turbines greater than 100 kW, 2013–2022

Annual installations vary across the states, as illustrated in Figure 4 and Figure 5. Figure 4 shows states with cumulative distributed wind capacities greater than 20 MW. Figure 5 shows states with cumulative small wind capacities greater than 2 MW.

Iowa and Minnesota lead all the states in cumulative capacity from 2003 through 2022, with both states exceeding 100 MW, as shown in Figure 4. Both states have strong wind resources and active project developers. Both states have also received the largest share of U.S. Department of Agriculture (USDA) Rural Energy for America Program (REAP) funding for wind projects since 2003 (see Section 4.1.3). Wisconsin exceeded 20 MW of distributed wind capacity because PNNL was able to add new-to-PNNL project records from past years to the dataset.

Iowa, Alaska, and Nevada are the top three states for cumulative small wind capacity, as shown in Figure 5, although there were no new small wind installations recorded for Alaska and Nevada in 2022. New York led the United States in annual small wind capacity additions from 2017 through 2020, but installations declined following the discontinuation of the New York State Energy and Research Development Agency (NYSERDA) Small Wind Turbine Incentive Program. In addition to reaching 20 MW of overall distributed wind capacity, Wisconsin also exceeded 2 MW of small wind capacity because of the additional new-to-PNNL project records.

Minnesota added the most small wind capacity in 2022 with 327 kW, primarily as a result of Eocycle Technologies, Inc.'s continued push to sell its EOX-S16 turbine model to farmers in Minnesota to provide a decarbonization solution for the emissions-heavy agriculture industry (Eocycle 2021; Mogensen 2022). Vermont added the next most with 152 kW of small wind capacity in 2022 to reach a cumulative small wind capacity of 1.3 MW. Most of the capacity in 2022 was from six 25-kW Star Wind STAR72 turbines connected to a load-serving distribution line via the Vermont Standard Offer Program, which is designed to encourage development of renewable energy resources by making long-term contracts at fixed prices available to qualified facilities (VEPP 2023).

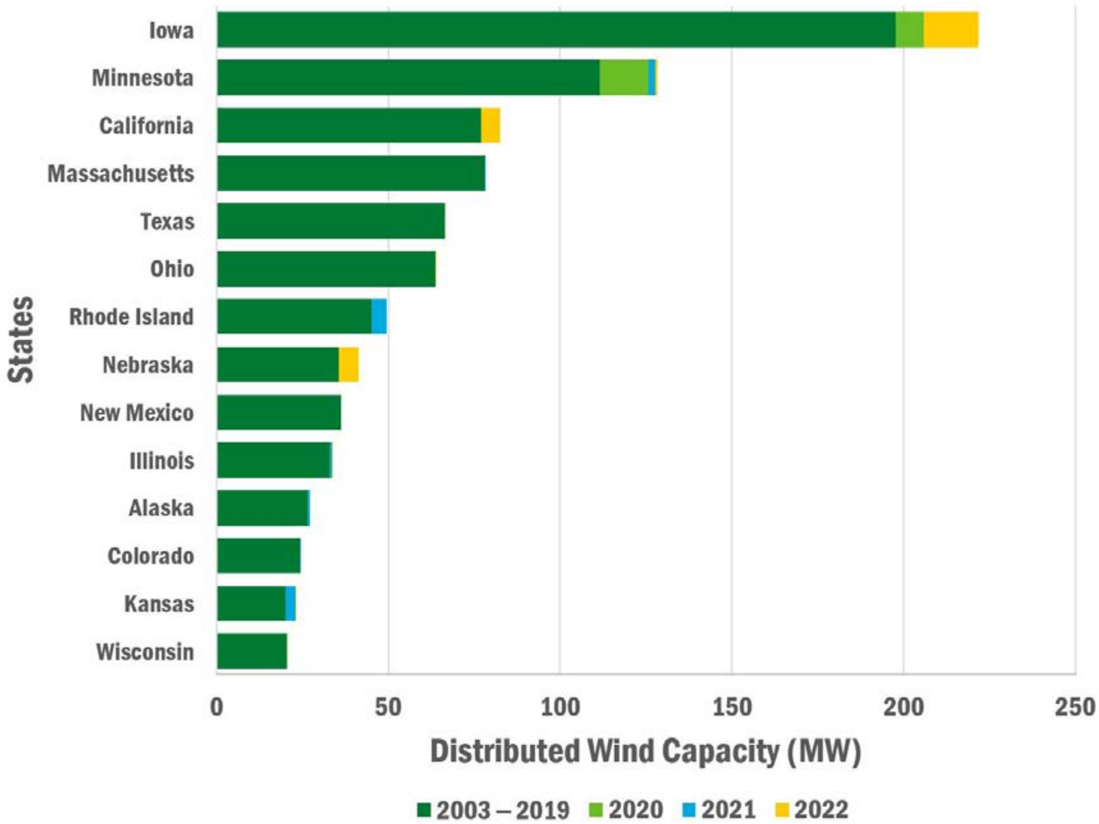

Figure 4. States with distributed wind capacity greater than 20 MW, 2003–2022

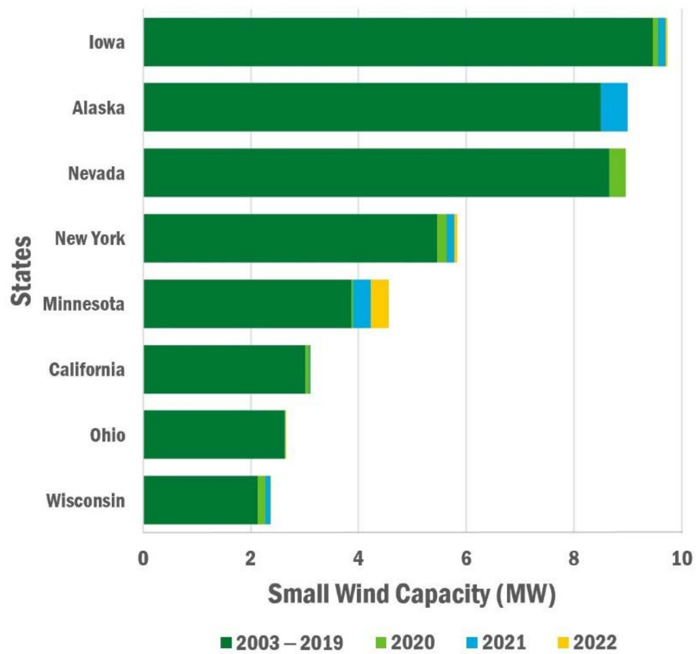

Figure 5. States with small wind capacity greater than 2 MW, 2003–2022

2.2 Project-Development Timelines

Based on an evaluation of a sample of projects installed between 2016 and 2022, distributed wind project development is estimated to last about two years on average. The full length of project development can be defined as the period from first customer contact to the commissioning of the project. As the PNNL team does not have access to these dates for all the projects in PNNL's dataset, other project milestones (e.g., the period between incentive program application and payment) were used to gauge minimum estimated timelines for distributed wind project development. The time between these interim milestones, within the full project development timeline, can be seen as the minimum length of time required for project development as other activities must happen before and after these interim milestones.

The PNNL team used project records from 2016 to 2022 to keep the analysis current while ensuring a reasonable sample size. Project records were sourced from the Federal Aviation Administration (FAA) database, the NYSERDA Small Wind Turbine Incentive Program, and the California Self-Generation Incentive Program (SGIP).

During project development, a project developer must file a Notice of Construction with the FAA if the turbine structure meets a requirement from a list of FAA-provided requirements (FAA 2023). For projects with FAA filings, the PNNL team analyzed the time between when the Notice of Construction was entered into the FAA database ("EntDate," entered date) and when the turbine and tower were erected ("DtBuilt," built date) to estimate a minimum project development timeline for this dataset. For the 64 turbines with FAA filings analyzed, the average timeline between the entered data and built date was 1.2 years with a median of 0.99 years. The sample of FAA turbines ranges in size from 3.6 kW to 2.82 MW. Projects in the Midwest, which make up 58% of the sample, generally had the shortest timeline (i.e., 0.76 years). The longest average timeline was in the West (i.e., 2 years). Turbine size had no noticeable effect on the period of time analyzed—small wind turbines had an average timeline of 1.24 years, while large-scale turbines averaged 1.2 years.

NYSERDA filings for this analysis included 90 turbines that range in size from 1.7 kW to 1.5 MW. NYSERDA staff tracked the date the incentive application was filed and the date of turbine interconnection, in addition to other milestones. The date the project owner filed the incentive application was used as the start date of the NYSERDA incentive review timeline, while the interconnection date was used as the end date (with incentives paid at interconnection), to estimate a minimum project development timeline for this dataset. The NYSERDA incentive review timeline averaged 1.3 years with a median of 1.2 years. All but one of the 90 turbines in the NYSERDA sample are small wind turbines, with the large-scale turbine taking 1.6 years to complete the minimum development cycle.

The PNNL team also analyzed distributed wind projects that received an incentive from the California SGIP. This dataset has a small sample size of six projects, all using large-scale turbines ranging in size from 1.7 MW to 2.82 MW. For each application, the California SGIP records the date the incentive application was filed and the date of turbine interconnection, in addition to other milestones. The PNNL team used the SGIP incentive review timeline, from the incentive application filing date to the interconnection date (with incentives paid sometime after interconnection), to estimate a minimum project development timeline for this dataset. This timeline averaged to 1.94 years with a median of 1.87 years. While the incentive review timelines for both NYSERDA and California SGIP projects are based on the same milestones, the small sample of distributed wind projects that received California SGIP incentive had longer incentive review timelines than the projects that received the NYSERDA incentive.

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

As shown in Figure 1, of the 29.5 MW of distributed wind added in 2022, 27.2 MW came from projects using turbines greater than 1 MW (92%), no capacity came from midsize turbines (0%), and 2.3 MW came from small wind (8%).

3.1 Midsize and Large-Scale Turbines

In 2022, 27.2 MW of distributed wind using large-scale turbines was deployed in the United States from four projects using 10 turbine units representing $69 million in investment. [13] This is an increase from 8.7 MW from three projects using five large-scale turbine units representing $30 million in investment in 2021 and 20 MW from five projects using eight large-scale turbines representing $36 million in investment in 2020.

There were no reported distributed wind projects in 2022 that used midsize turbines. In 2021, a total of 1.2 MW of midsize capacity from three projects using four turbines was deployed representing $2 million in investment, compared to 0.28 MW from two single-turbine projects in 2020 representing $0.4 million in investment.

Projects using midsize turbines have regularly represented a small part of the distributed wind market in recent years. This limited market share can be attributed to the limited number of midsize turbine models available and the expectation that larger turbines can be more cost effective (although refurbished[14] midsize turbines can have lower capital costs than newly manufactured midsize turbines as shown in Figure 12 in Section 5.2). Added capacity from midsize turbines has been under 5 MW annually since 2013 and has consisted of predominantly single-turbine projects.

However, the midsize turbine market continues to see interest both from manufacturers and DOE research and development investment. One midsize turbine from India-based Siva Wind was installed in 2021 and Siva Powers America, the U.S. subsidiary of Siva Wind, plans to open a manufacturing facility in New York in late 2023 or early 2024 (Joe 2023), implying the company expects there to be growth in the domestic midsize turbine market. In addition, the WETO-funded Competitiveness Improvement Project (explained in Section 4.2.3) has funded a few midsize turbine manufacturers to improve turbine model design, performance, and costs. Siva Powers America (New York) was funded in 2021 to test new prototype blades for its 250-kW turbine (NREL 2022a), Carter Wind Turbines (Oklahoma) was funded in 2022 to develop a taller tower for its 300-kW turbine, and RRD Engineering (Colorado) was funded in 2022 to pursue development of a 150-kW turbine (Laurie 2022).

Manufacturer representation in U.S. distributed wind projects changes from year to year and the midsize and large-scale turbine markets often rely on imports. However, some manufacturers are consistently represented in distributed wind projects and manufacturer representation is tied to the project-development cycle of the developers featured in Figure 3. General Electric (GE) Renewable Energy has been the only consistent U.S.-based[15] manufacturer of large-scale turbines used in distributed wind projects over the past ten years and is the turbine provider for Foundation Windpower, Bluestem Energy Solutions, ConEdison Development, and Juhl Energy's most recent projects. As a result, only GE wind turbines were deployed in distributed wind projects using turbines greater than 100 kW in 2022, as shown in Figure 6. China-based turbine manufacturer Goldwind is the sole turbine supplier for One Energy Enterprises LLC, and Green Development uses turbine models from the Germany-based manufacturer Vensys.

[13] This investment value reflects the estimated installed cost of the deployed capacity, not just the turbine hardware costs. The same is true for the small wind investment value presented in Section 3.2.

[14] A refurbished turbine may be one that only had a few new parts added to it 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.

[15] U.S.-based means the manufacturer or supplier is headquartered in the United States.

Developers, particularly those that also operate the distributed wind projects they build and sell the power through power purchase agreements to customers, report that they source all of their wind turbines from one manufacturer to facilitate easier O&M across their fleet of projects. This sole sourcing allows them to train workers, build inventories of spare parts and consumables, and remotely monitoring the fleet based on only one manufacturer's turbine models.

Manufacturers with turbines deployed in three or more years are shown separately in Figure 6. Manufacturers with turbines deployed in fewer than three years in the 10-year period shown in Figure 6 are grouped in the "other" category. For turbines greater than 100 kW, a total of 25 manufacturers and suppliers provided turbines for distributed wind projects in 2012, a peak year for distributed wind capacity additions, compared to one in 2022, six in 2021, and two in 2020. In Figure 6, three manufacturers are represented in the "other" category in 2021 and one in 2020 (compared to 17 "other" manufacturers in 2012).

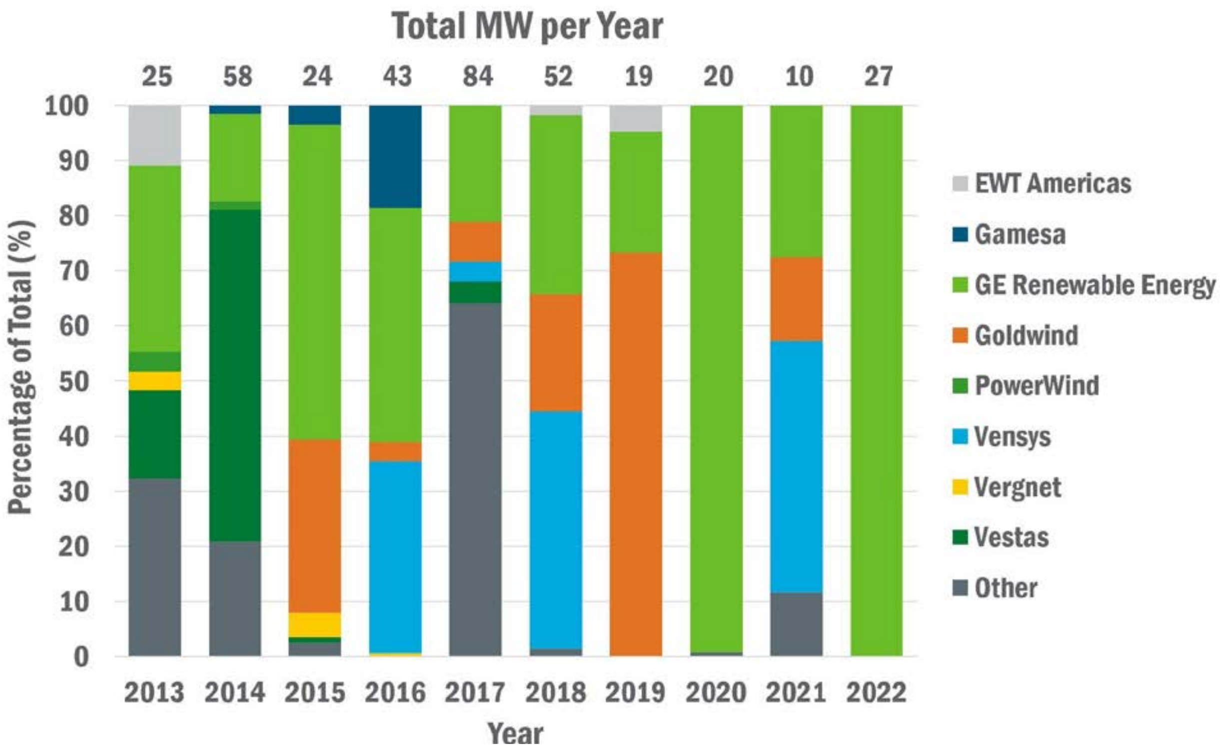

Figure 6. Wind turbine manufacturers of turbines greater than 100 kW with a U.S. sales presence, 2013–2022

3.2 Small Wind

In 2022, 2.3 MW of small wind was deployed in the United States from 1,745 turbine units representing $14.6 million in investment. The capacity and investment amounts are up from 1.8 MW, 1,742 turbine units, and $9.2 million in 2021 and 1.6 MW, 1,487 turbine units, and $7.2 million in 2020. All small wind manufacturers and suppliers who responded to PNNL's data request reported higher sales in 2022 than in 2021.

Since 2012, when a total of 31 small wind turbine manufacturers had reported U.S. sales in 2012, the number of small wind turbine manufacturers both operating and participating in the U.S. market has generally been on the decline. Some small wind manufacturers do not have consistent sales from year to year, some go out of business, and some—particularly foreign manufacturers—focus on other countries with policies supportive of distributed wind. Additional factors causing the market contraction include the unstable policy environment in the United States and competition from solar photovoltaic (PV) systems.

Eight small wind turbine manufacturers or suppliers reported sales in 2022 for this report (listed in Appendix A) and consist of six domestic manufacturers headquartered in six states (i.e., Colorado, Minnesota, New York, Oklahoma, Texas, and Vermont) and two foreign manufacturers. This is down from 13 manufacturers or suppliers who reported sales in 2021 (nine domestic and four foreign) but equal to the eight manufacturers or suppliers (six domestic, two foreign) that had a U.S. sales presence in 2020.

The top three small wind turbine manufacturers, with respect to capacity (MW) sold in the U.S. market in 2022, were Eocycle Technologies, Inc. of Canada, Bergey WindPower of Oklahoma, and Primus Wind Power of Colorado.

Some small wind turbine manufacturers reported that pandemic-related supply chain constraints and increased costs for raw materials were still factors affecting their businesses in 2022. But with new and extended incentives in the Inflation Reduction Act (IRA) of 2022 (enacted as Public Law 117-169 on August 16, 2022) and the expanded USDA REAP (see Sections 4.1.2 and 4.1.3), small wind turbine manufacturers are expecting higher sales in 2023.

Two small wind turbine manufacturers are poised to reenter the U.S. market after leaving in 2019: Northern Power Systems (NPS) and the new owner of the Skystream 3.7 turbine model. NPS shared with PNNL that the company has a new U.S. subsidiary, NPS Solutions LLC, which is owned by the Italian parent organization, NPS Srl. NPS will continue to manufacture its turbines in Italy until a sales volume can justify bringing manufacturing back to the United States. In early 2023, a holding company for DeBruce Family Companies, Wind Resource, LLC, purchased the Skystream turbine model line.

The aggregated capacity and units sold reported by U.S.-based small wind turbine manufacturers and refurbished[16] small wind suppliers stayed relatively flat from 2021 to 2022, as shown in Figure 7. While the capacity of imports from non-U.S. small wind turbine manufacturers increased by 144% from 2021 to 2022, the number of units decreased by about 30%. A total of 90% of the imported turbine units sold in 2021 were from manufacturers selling units 6 kW or less in nameplate capacity, but about 60% of the imported turbine units sold in 2022 were 25 kW or greater in nameplate capacity. This change can be attributed to the inconsistent presence (or reporting) of non-U.S. manufacturers in the U.S. small wind market. Two foreign small wind manufacturers reported sales in the United States in 2022 compared to four in 2021 and two in 2020.

3.3 Small Wind Exports

U.S. small wind turbine manufacturers also export to international markets. Since 2014, more than 50 MW of U.S. small wind turbines have been exported globally, but these exports have significantly declined from a peak of 21.5 MW from six U.S.-based manufacturers in 2015 to just 168 kW from five manufacturers in 2022, 134 kW from three manufacturers in 2021, and 192 kW from three manufacturers in 2020.

Italy, the United Kingdom, and Japan had been key export markets for U.S. small wind turbine manufacturers due to those countries' feed-in tariff (FIT) programs. In the peak year for exports, 2015, 99% of U.S. small wind turbine manufacturers' exports went to these three countries. The FIT programs in Italy, the United Kingdom, and Japan have since been discontinued or drastically reduced, thus reducing the attractiveness of these markets for U.S. small wind turbine manufacturers.

[16] Most refurbished turbines deployed in the United States were originally manufactured by a non-U.S.-based manufacturer and then refurbished by a U.S.-based supplier.

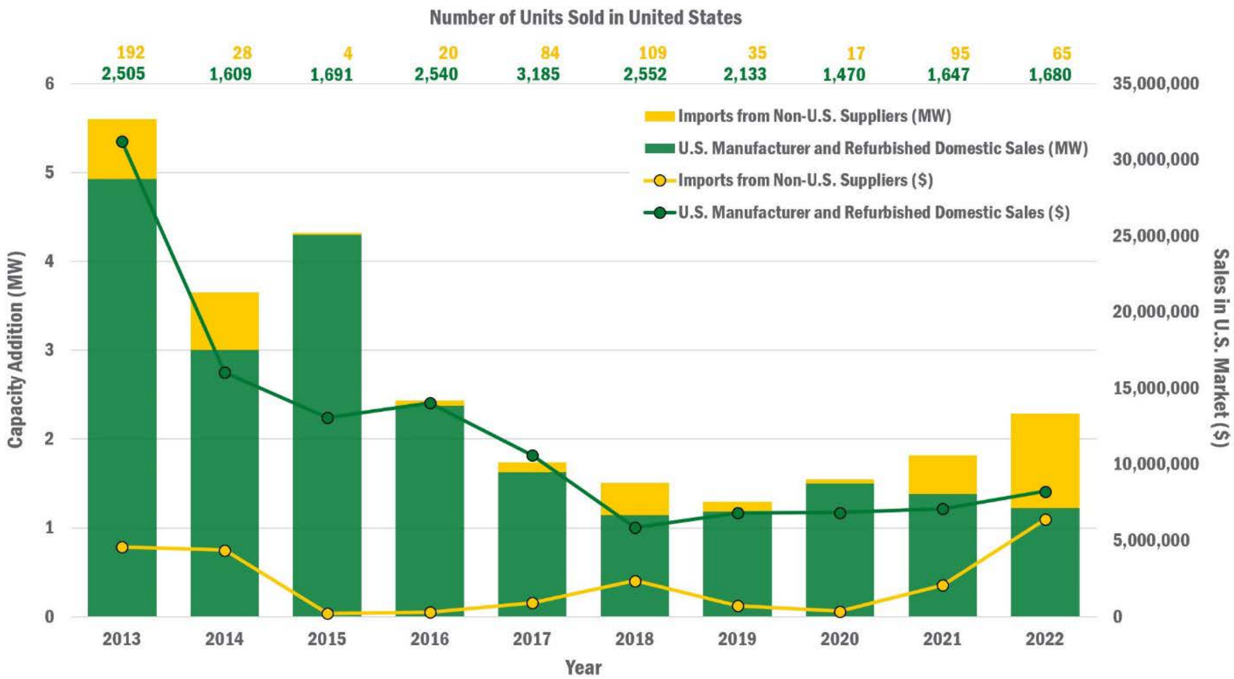

Figure 7. U.S. small wind turbine sales, 2013–2022

3.4 Global Small Wind Market

An examination of the global small wind market provides additional context for small wind market trends and a point of comparison for the U.S. small wind market. For 2022, the PNNL team documented about 72 MW of new small wind capacity from six countries, including the United States, as shown in Table 1. The China Wind Energy Equipment Association reported a total of 60 MW, or 84%, of the capacity deployed in 2022.

The PNNL team depends on agencies in other countries to report their statistics—and not all countries track small or distributed wind deployment. That dependency can result in an incomplete picture of the global market. Other countries, not included in Table 1, may have different market situations.

Total global installed cumulative small wind capacity is estimated to be at 1.9 gigawatts (GW) as of 2022. Small wind is generally defined as turbines up through 100 kW, but can vary according to country. Those distinctions are noted in Table 1.

Countries across the globe face similar technical, economic, market, and performance challenges to distributed wind market expansion. However, each market also has its own unique opportunities. The International Energy Agency Wind Technical Collaboration Programme Task 41 is focused on advancing wind as a distributed energy resource. Task 41 researchers are collaborating to address the challenges and promote the opportunities in the following sections.

3.4.1 Asian Markets

The Asian markets of China, Japan, South Korea, and India reported challenges in their respective small wind sectors in recent years (Kim 2023; WWEA 2023). In China, only a small number of small wind turbine manufacturers remain, in part due to the rapid advancement and adoption of solar PV. However, the 60 MW of small wind installed in China in 2022 is an 81% increase from 2021 to 2022. Additionally, the Chinese small wind market anticipates future export opportunities for off-grid turbines in countries with underdeveloped power grids and areas with frequent power outages (Yu 2023).

Table 1. Global Small Wind Capacity Reports (MW)

Country	2013–2019	2020	2021	2022	Cumulative	Cumulative Years	Small Wind Definition	Reference
Argentina	a	a	a	a	6.50	As of 2022	Uncertain	(Associacíon Argentina de Energia Eólica 2023)
Australia	0.08	0.00	0.00	0.00	1.47	2001–2022	0–10 kW capacity	(Australian Government 2023)
Austria	a	a	a	a	0.29	As of 2022	0–50 kW capacity	(University of Applied Science Technikum Wien 2023)
Brazil	0.29	0.07	0.20	0.06	0.62	2013–2022	0–75 kW capacity	(Brazil National Electric Energy Agency 2023)
Canada	a	a	a	a	13.47	As of 2018	Uncertain	(Canadian Government 2018)
China	315.39	25.65	33.38	60.32	704.32	2007–2022	0–100 kW capacity	(China Wind Energy Association 2018; China Wind Energy Equipment Association 2023)
Denmark	61.08	0.05	0.04	0.18	611.09	1977–2022	0–100 kW capacity	(Danish Energy Agency 2023)
Germany	8.70	2.50	2.50	1.50	39.75	As of 2022	0–50 kW capacity	(Klein-Windkraftlagen 2023)
India	a	a	a	a	5.00	As of 2022	0–10 kW capacity	(Hossain 2023)
Italy	169.04	1.10	3.01	7.25	200.78	As of 2022	0–250 kW capacity	(Gestore dei Servizi Energetici 2023)
Japan	a	a	a	a	12.88	As of 2019	0–20 kW capacity	(Japan Small Wind Turbine Association 2020)
New Zealand	a	a	a	a	0.19	As of 2015	Uncertain	(Sustainable Electricity Association of New Zealand 2016)
South Korea	1.09	a	a	a	4.08	As of 2019	Uncertain	(Korean Energy Technology Evaluation and Planning 2020)
United Kingdom	63.93	a	a	a	141.51	As of 2019	0–100 kW capacity	(United Kingdom Government 2019)
United States	20.65	1.55	1.82	2.30	156.77	2003–2022	0–100 kW capacity	This report
Global	640.24	30.91	40.95	71.61	1,898.71	As of 2022	As defined above	The sum of the table

a Data not available

Challenges to establishing a strong small wind market in Japan include turbine cost; lack of standardization in production, distribution, and construction across manufacturers; social acceptance; and supply chain constraints (Kubo 2023). Distributed wind deployment in South Korea has been limited due to social acceptance and lack of financial support; however, the government is beginning to consider introducing a new law for the vitalization of distributed energy (Kim 2023).

The Indian small wind market was negatively impacted when a government program supporting small wind turbines and hybrid systems ended in 2019. However, several small wind turbine manufacturers remain active producing a wide range of turbine sizes and options (Hossain 2023).

3.4.2 European Markets

Across Europe, small wind turbines supply power to various applications including island grids, agricultural operations, telecommunications towers, hydrogen production, and local heating demand (Ogg 2023). In the United Kingdom, three market growth drivers are telecommunications and critical infrastructure, community power, and the repowering FIT (Munro 2023), the last of which allows current turbine owners to repower without compromising their FIT accreditation (Ofgem 2021). There are currently no wind turbine manufacturers in Ireland, but agents from the United Kingdom are involved with distributed wind installation, operations, and maintenance in Ireland and new wind projects are being explored for agricultural, electric vehicle, and off-grid applications (Byrne 2023).

For Italy, experts in the country have reported that small wind turbines are not yet fully competitive with other traditional and renewable generation technologies. However, new turbine technologies have the potential to receive incentives if used in Italy’s Renewable Energy Communities, which are several entities connected to the same secondary substation using the preexisting distribution grid, under the Italian Legislative Decree No. 199/2021 (Castellani and Pagnini 2023; Fabbricatore 2023).

An Austrian policy enacted in 2022, requiring stricter inverter regulations, has impacted that country’s small wind market, as many manufacturers do not have an inverter that meets the new standards (Hirschl 2023).

The Spanish small wind market is evolving slowly due to an imbalance between turbine affordability and quality; however, high electricity prices on the country's islands are stimulating the use of distributed wind in those locations (Cruz 2023). In July 2020, Greece introduced a licensing procedure for wind projects with installed capacities of less than 60 kW. Since then, two small wind turbine types have received certification approval, but no installations have occurred yet (Stefanatos and Rossis 2023).

3.4.3 North and South American Markets

In Canada, despite investment in off-grid renewables from the Canadian government to reduce dependence on diesel, barriers such as slow project-development cycles and limited turbine adaptability to cold climates have resulted in slow distributed wind growth since 2016 (Bolduc 2023). In Argentina, small wind installations are stalled due to high acquisition and installation costs and high maintenance costs due to distance and access challenges in rural areas (Pagani 2023).

4 Policies, Incentives, and Market Insights

Several factors affect the U.S. distributed wind market, including the availability of, and changes to, 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) are important to the development of distributed wind and other distributed energy resource projects.

Figure 8 shows the value of incentives given to distributed wind projects from 2013 to 2022, excluding federal production and investment tax credits.[17] The combined value of USDA REAP grants and state production tax credits (PTCs) in 2022 was $5 million across eight states (i.e., Iowa, Kansas, Minnesota, Missouri, Nebraska, New Mexico, New York, and Vermont). This is roughly the same as the $5.2 million paid across eight states in 2021 and the $4.8 million paid across six states in 2020, although those past year totals include other incentive payments in addition to USDA REAP grants and state PTCs.

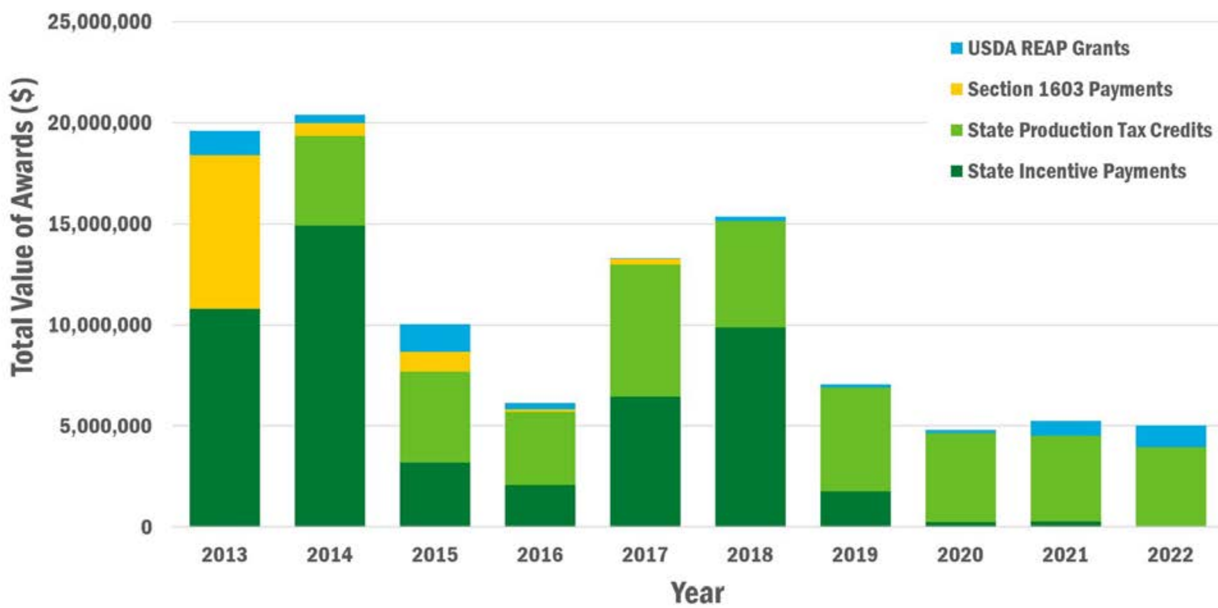

Figure 8. U.S. distributed wind incentive awards, 2013–2022

Figure 8 includes USDA REAP grants; U.S. Treasury cash grants (otherwise known as Section 1603 payments); state PTCs (which are only offered by New Mexico and Iowa); and state incentive programs that provide cash rebates, grants, and performance-based payments. The PNNL team started tracking the New Mexico and Iowa state PTCs in 2014, when the New Mexico credit was first initiated. Figure 8 excludes repaid loans, the federal Business Energy Investment Tax Credit (ITC), the federal Residential Energy Tax Credit, the federal Renewable Energy PTC, federal depreciation, and USDA High Energy Cost Grants. The federal tax credits are excluded because information on how many wind projects have claimed them is not public record. USDA High Energy Cost Grants are for areas with extremely high per-household energy costs. They are excluded from Figure 8 because the grants typically cover full systems with multiple technologies (e.g., new

[17] Distributed wind projects often receive incentive funding at a different time than when they are commissioned. 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 and this can be up to two years after the award.

wind turbines, boilers, and electric thermal storage devices) and the value of the grant for the wind portion cannot be distinguished. New Mexico and Iowa state PTC values are estimated based on available project energy production reports.

Iowa PTC payments are decreasing as some projects have completed their 10-year eligibility period. The last Section 1603 payments were made in 2017 (Treasury 2018).[18] The decline in state incentives is explored in Section 4.1.1. Federal tax-based incentives are discussed in Section 4.1.2. USDA REAP wind applications and grants are discussed in Section 4.1.3.

4.1.1 State Policy and Cash Incentive Highlights

No state programs reported cash incentive payments for distributed wind projects in 2022. With the expiration of the NYSERDA Small Wind Turbine Incentive Program, the California SGIP is the last state cash incentive program the PNNL team is aware of that regularly provides funding to distributed wind projects. Based on the PNNL team's review of public California SGIP reports, the program is expected to make incentive payments in 2023 for projects installed in previous years.

4.1.2 Federal Tax Incentives

The federal Business Energy ITC (26 U.S.C. § 48) and the Residential Renewable Energy Tax Credit (26 U.S.C. § 25D) are federal policy mechanisms that offset some of the capital costs of qualified renewable energy projects. The IRA extended the Residential Renewable Energy Tax Credit at 30% through 2032, then the credit value is phased down until it expires in 2035. The IRA also extended the Business Energy ITC at 30% through 2024. Provisions allow for additional, stackable bonus credits by meeting "energy community" or domestic content requirements. Communities with brownfields, high fossil fuel employment or tax revenue with higher-than-average unemployment rates, or that have recently closed coal mines or coal-fired electric generation plants are considered energy communities. Further ITC bonuses up to 20 percentage points are available on a limited, competitive basis for wind or solar (and from 2025 on other clean energy) projects less than 5 MW that are located in or benefit low-income communities or are located on tribal lands. Starting in 2025, the ITC will be replaced by the Clean Electricity ITC that will be available to all energy-generation technologies with zero or net-negative carbon emissions, and for which the same bonus credits will be available (WETO 2023).

The IRA also provides a direct-pay and transferability provision on the Business Energy ITC and forthcoming Clean Electricity ITC. This direct-pay provision is for non-tax-paying entities that cannot directly monetize a tax credit incentive, such as nonprofits, tribes, Alaska Native Corporations, and rural electric cooperatives.

The IRA also extended the federal Renewable Energy PTC (26 U.S.C. § 45) for land-based wind through 2024 at a rate of $27.50/MWh for 2022 and increasing with inflation. In 2025, the current PTC will be replaced by the technology-neutral Clean Electricity PTC. The PTCs are also eligible for direct-pay and transferability, and include similar but less valuable (10% vs. 10 percentage points for the ITC) bonus credit provisions as the Clean Energy ITC.

4.1.3 USDA REAP

The USDA provides agricultural producers and rural small businesses grant funding and loan financing to purchase or install renewable energy systems or make energy-efficiency improvements. The IRA includes up to $2.025 billion of funding allocated for USDA REAP, with $303 million set aside for underutilized technologies and technical assistance. Wind is an eligible underutilized technology. IRA funds are anticipated

[18] The federal ITC was temporarily augmented in 2009 to allow for cash payments from the federal government in lieu of the tax credit, otherwise known as the U.S. Treasury cash grants or Section 1603 payments. To qualify for Section 1603 payments, wind power projects must have (1) applied for a grant before October 1, 2012, and been placed in service by 2011, or (2) began construction in 2009, 2010, or 2011, and been placed in service by December 31, 2016. Because payments were made after the project was placed in service, not prior to or during construction, payments continued through 2017.

to support renewable energy and energy-efficiency projects for more than 41,500 farms and small businesses (USDA 2023). The new IRA provisions for REAP also doubled the maximum allowable grant size from $500,000, or 25% of costs, to $1,000,000, or up to 50% of costs, for renewable energy projects. The USDA also issues loan guarantees for renewable energy projects for up to 75% of the project's cost or a maximum of $25 million. A combination of REAP loans and grants can cover up to 75% of total eligible project costs.

REAP also has a new scoring rubric for grant applications submitted on and after April 1, 2023. Scoring points are awarded for the following criteria (USDA 2023):

- energy generated, saved, or replaced
- whether the applicant is a previous award recipient
- length of payback period
- whether the project is located in a disadvantaged community or a distressed community
- commitment of matching funds
- environmental benefits
- state director/administrator points.

A new criterion is project location in a disadvantaged or distressed community, which replaces a former criterion about the size of the funding request and has a higher maximum point score than the criterion it replaces. In addition, USDA REAP changed the point allocations for environmental benefits (higher) and commitment of matching funds (lower) to keep the total possible score at 100 points.

In 2022, USDA REAP awarded $1,069,922 in grants to 12 wind projects (Figure 9). The 12 projects represent a total of 4.8 MW of capacity from 19 turbines in six states (i.e., Kansas, Minnesota, Missouri, Nebraska, New York, and Vermont). The projects are expected to generate a combined 24.6 GWh of energy annually. The 2022 funding amount was substantially greater than the $696,964 in wind grants awarded in 2021 to 22 projects in five states. The increase can be attributed to the large USDA REAP grant for the 5.64-MW project installed in Nebraska by Bluestem Energy Solutions, which accounts for 47% of the total grant funding for wind projects in 2022, rather than an increase in the number of awards.

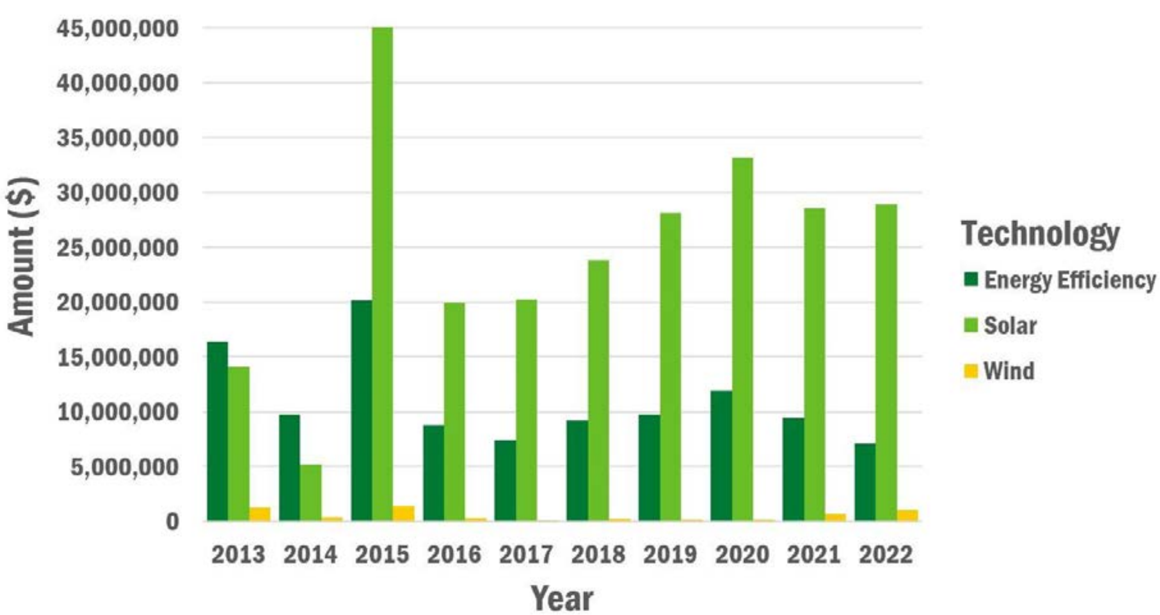

Figure 9. USDA REAP grants by technology, 2013–2022

Wind projects represented 1.5% of all 2022 REAP grant awards and 2.7% of all 2022 REAP grant funding, while energy-efficiency projects represented 20% of grant awards and 18% of grant funding; and solar PV projects represented 76% of grant awards and 72% of grant funding. Other renewable energy awards include biogas, biomass, geothermal, and hydroelectric projects. In 2021, wind projects represented 1.7% of all REAP grant awards and 1.5% of REAP grant funding.

USDA REAP did not provide any loan guarantees to wind projects in 2022. With respect to loans over the period of 2013 to 2022, there was only one loan guarantee for a distributed wind project in 2018. In 2022, 29 loans were guaranteed to solar PV projects, down from the record number of 76 loans guaranteed in 2021.

Since 2003, the USDA has awarded over $74 million in REAP wind grants. States with projects receiving the largest share of this funding include Iowa with $23.3 million, Minnesota with $21.9 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 include Iowa with 265, Minnesota with 192, New York with 51, Wisconsin with 45, and Alaska with 30. Despite holding the largest cumulative share of REAP awards, Iowa has only received one REAP award since 2017: a $3,901 grant in 2020. Minnesota received a total of $652,141 in REAP wind grant awards in 2021 and 2022.

4.2 Market Insights

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

4.2.1 Small Wind Repowers

To be in alignment with typical industry language, the PNNL team will use the term repower, rather than retrofit, going forward in Distributed Wind Market Reports. Repowers are new (i.e., either newly manufactured or refurbished) turbines installed on existing towers and foundations to replace nonfunctioning turbines or to upgrade the technology.

Repowers accounted for a reduced portion of new small wind capacity deployment in 2022 compared to previous years. In 2022, small wind repowers represented just 8% of total installed small wind capacity, compared to 36% in 2021 and 79% in 2020.[19] This fluctuation is a result of how many customers an installer can manage in a year, turbine supply availability, and each year's sample size of reported projects.

The repower trend is largely driven by customers' interest in reusing existing infrastructure to maintain on-site wind generation. The PNNL team will continue to monitor repowering reports as many small wind turbines reach the ends of their life cycles and customers seek out improved technologies.

4.2.2 Hybrids and Co-Located Distributed Energy Resources

For each entry in the master project dataset, PNNL documents, if known, whether the distributed wind turbine is part of a hybrid power plant, part of a hybrid power system, or has co-located distributed energy resources.

Co-located and co-operated energy resources with shared components and control strategies are the characteristics that most typically define a hybrid power plant or system (Murphy et al. 2021; Ahlstrom et al. 2019). Wind and solar generation can be complementary, and this resource diversity can allow a wind-solar hybrid to achieve a more consistent renewable generation profile throughout the year (Clark et al. 2022; Reiman et al. 2020). A

[19] The percentage values for repowers may differ from what was presented in previous reports because PNNL regularly adds project records from previous years to its master project dataset.

homeowner with a small wind turbine and rooftop solar PV can also benefit from the complementarity, even if the two resources are simply co-located to serve the same house but are not controlled together.

Hybrid power plants are being installed at all scales, including at the distribution level. Building on the success of the 2-MW wind-solar hybrid power plant developed by Juhl Energy and interconnected to the Lake Region Electric Cooperative distribution system (Moorefield 2021), Dan Juhl, with other founding members, formed a new company, Hybrid Renewables LLC, in 2022 (Hybrid Renewables 2023). With the direct-pay provision of the ITC under the IRA, additional tax-exempt cooperatives may be motivated to pursue hybrid power plants for their distribution systems.

4.2.3 Competitiveness Improvement Project

The Competitiveness Improvement Project, which is funded by WETO and administered by the National Renewable Energy Laboratory (NREL), awards cost-shared subcontracts via a competitive process to manufacturers of small and medium[20] wind turbines. The goals of the Competitiveness Improvement Project and WETO's Distributed Wind Research Program are to make small and medium wind energy technologies cost competitive with other distributed generation technologies and to increase the number of small and medium wind turbine designs tested and certified to national performance and safety standards. Since 2012, NREL has awarded 64 subcontracts to 26 companies, totaling $15.4 million of DOE funding and leveraging $7.9 million in additional private-sector investment (NREL 2023a).

Fiscal year 2022 and 2023 funding for the Competitiveness Improvement Project was combined and awardees for 2022 and 2023 were announced on December 15, 2022 (NREL 2023a). Consequently, the next solicitation will tentatively be in 2024. The awardees will use their cost-shared subcontracts to:

- develop optimized designs for increased energy production and grid support
- conduct turbine and component testing to national standards to verify performance and safety
- develop advanced manufacturing processes to reduce hardware costs
- commercialize optimized technology to accelerate deployment.

4.2.4 Certified Small and Medium Turbines

Certifying a small or medium turbine model to consensus standards provides a method for manufacturers to demonstrate that the turbine model meets design, performance, and quality requirements and establishes common performance metrics to enable performance comparisons. Certifications issued by independent, accredited third-party certification bodies allow wind turbine manufacturers to demonstrate compliance with regulatory and incentive program requirements. In addition, certified ratings allow purchasers to directly compare products and give funding agencies and utilities greater confidence that small and medium turbines installed with public assistance comply with applicable standards.

As of January 2015, small wind turbines must meet either the AWEA Small Wind Turbine Performance and Safety Standard 9.1-2009 or the International Electrotechnical Commission (IEC) 61400-1, 61400-11, and 61400-12 standards to be eligible to receive the small wind Business Energy ITC (IRS 2015).[21] These standards address power performance, structural design, safety, and acoustic sound requirements.

The ACP, the successor to AWEA, published its new ANSI consensus standard, ANSI/ACP 101-1-2021, in October 2022 (ANSI 2023). The ANSI/ACP 101-1 standard defines small wind turbines as having a peak power of 150 kW or less and distinguishes microturbines as having a peak power up to 1 kW. The Distributed

[20] The International Electrotechnical Commission 61400-1 Standard defines small wind turbines as having rotor swept areas of up to 200 m^2 and medium wind turbines as having rotor swept areas of 200 m^2 to 1000 m^2.

[21] This certification requirement does not apply to wind projects that opt out of the PTC to 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.

Wind Energy Association and DOE have recommended that the U.S. Internal Revenue Service (IRS) to recognize legacy certifications to AWEA 9.1-2009 and new certifications to ANSI/ACP 101-1 going forward for small wind Business Energy ITC eligibility.

The ANSI/ACP 101-1 standard has been designed to facilitate easier compliance, so the industry expects that new turbine models will be certified to this standard. Where certification to the AWEA standard took at least 12 months, certification to the ANSI/ACP standard is expected to take six months, primarily because the duration test is estimated to require four months for the ANSI/ACP standard but typically takes 10 months for the AWEA standard. Primus Wind Power was awarded a 2022–2023 CIP subcontract to test and certify its six turbine models to the new ANSI/ACP 101-1 standard.

The certification process is a significant upfront and ongoing cost for turbine manufacturers. High cost is one reason certification testing is supported by DOE through CIP. CIP award amounts are consistent with certification costs, about $150,000 to $200,000 for most small wind turbines. In addition to CIP subcontracts, NREL has initiated a subcontract with the International Code Council–Small Wind Certification Council (ICC-SWCC) through November 2024 to fund the organization to provide preliminary certification reviews (NREL 2023b). The preliminary reviews will determine if a turbine design is ready to complete the certification process successfully and ideally help more turbine manufacturers to start the certification process.

Table 2 lists the nine small wind turbine models certified to the AWEA 9.1 standard or the IEC 61400 standards as of June 2023. Wind Resource, LLC, the new owner of the Skystream 3.7 turbine model, recertified the turbine model in 2023 as part of its market return. While Table 2 lists its original certification date as 2023 because of the new ownership, the Skystream 3.7 turbine model was first certified in 2011.[22] Table 2 only includes those turbine models that have met annual renewal requirements. Manufacturers may opt not to renew if they no longer want to participate in the U.S. market or if the company has discontinued operations.

Table 2. Certified Small Wind Turbines as of June 2023[23]

Applicant	Turbine Model	Date of Initial Certification	Certified Power Rating[a] @ 11 m/s (kW)	Certification Standard
Bergey Windpower Company	Excel 10	11/16/2011	8.9	AWEA 9.1
Bergey Windpower Company	Excel 15	2/5/2021	15.6	AWEA 9.1
Eveready Diversified Products (Pty) Ltd.	Kestrel e400nb	2/14/2013	2.5	AWEA 9.1
Eocycle Technologies, Inc.	EOX S-16	3/21/2017	22.5/28.9	AWEA 9.1
HI-VAWT Technology Corporation / Colite Technologies	DS3000	5/10/2019	1.4	AWEA 9.1
Primus Wind Power	AIR 30/AIR X	1/25/2019	0.16	IEC 61400
Primus Wind Power	AIR 40/Air Breeze	2/20/2018	0.16	IEC 61400
SD Wind Energy, Ltd.	SD6	6/17/2019	5.2	AWEA 9.1
Wind Resource, LLC	Skystream 3.7	4/12/2023	2.1	AWEA 9.1

a Power output at 11 m/s (24.6 mph) at standard sea level conditions. Manufacturers may describe or name their wind turbine models using a nominal power, which may reference output at a different wind speed (e.g., 10-kW Bergey Excel 10)

While nine small wind turbine models have active certifications as of June 2023, at least 23 small wind turbine models have been certified to the AWEA or IEC standards between 2011 and 2022, as shown in Figure 10.

[22] The situation is similar for the SD Wind Energy SD6 turbine model. ICC–SWCC lists its original certification date as 2019, but it was first certified in 2013 as the Kingspan KW6 in 2013.
[23] Other information about these certifications, such as rated sound levels and rated annual energy production amounts, are available from the certification bodies (ICC–SWCC 2023; SGS 2021; UL 2021).

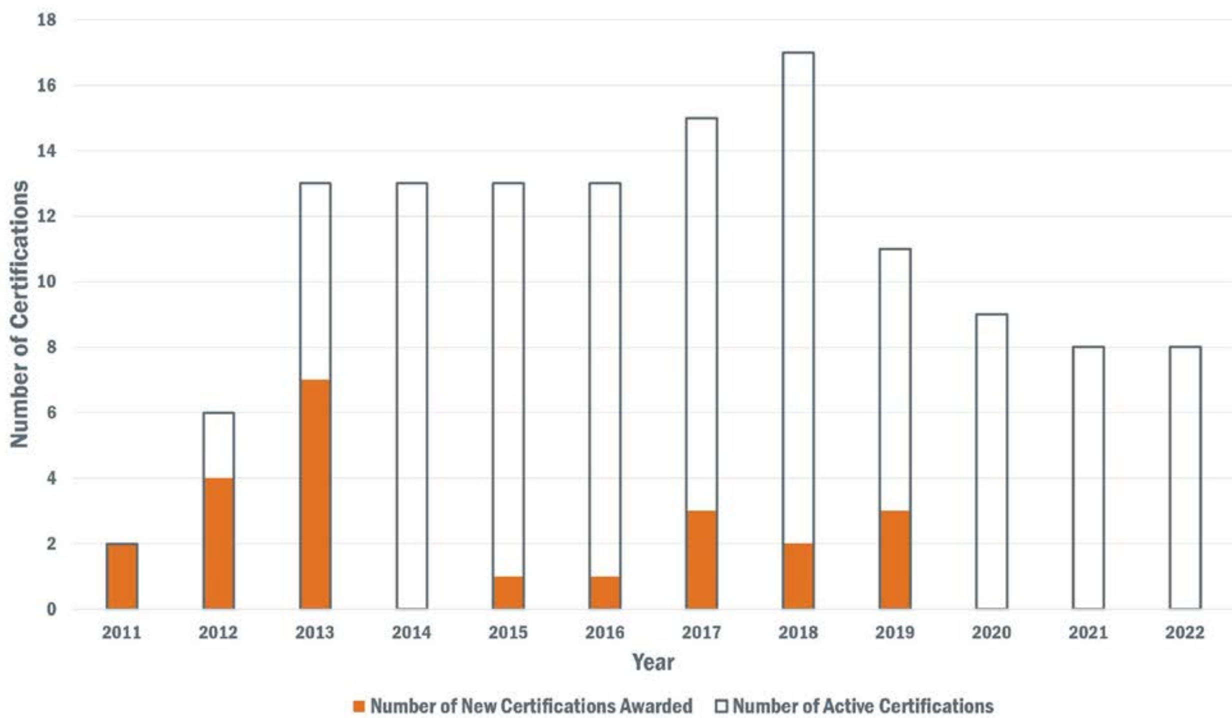

Figure 10. Small Wind Turbine Certifications, 2011-2022

After the certification of two turbine models in 2011, the number of annual certifications jumped in 2012 and 2013 with the establishment of the SWCC.[24] With startup funding from DOE, several state agencies, and NREL, the SWCC was officially accredited in 2012 (Orrell et al. 2013; Jones 2013).

The number of certifications awarded in a single year peaked in 2013, with seven new models of which more than half were certified by the SWCC. While the number of new certifications awarded each year dropped after 2013, the number of applicants who maintained active certifications (i.e., continued to recertify their models each year) peaked in 2018 at 17 turbine models.

The requirement that small wind turbines be certified to standards to be eligible for incentive payments from many state funding agencies motivated manufacturers to maintain their turbine model certifications. The Interstate Turbine Advisory Council (ITAC) was formed in 2011 and retired at the end of 2019 with the expiration of the NYSERDA Small Wind Turbine Incentive Program, which had been the last remaining ITAC member-incentive program. ITAC's objective was to establish an alliance of clean energy programs to facilitate a certification evaluation process that fit the performance and durability expectations of incentive providers (Stori 2014; CESA 2012). Its primary product was a list of small and midsized wind turbines that met the performance, reliability, acoustic and warranty service expectations of its incentive provider members. Its members included NYSERDA, the Energy Trust of Oregon, the Massachusetts Clean Energy Center, NV Energy, Minnesota Department of Commerce, New Jersey Board of Public Utilities, Alaska Energy Authority, and Pacific Gas & Electric (Stori 2014). Except for Pacific Gas & Electric, whose customers are eligible for the California SGIP, all the former ITAC members have discontinued their incentive programs. The drop in active certifications starting in 2019 can be attributed to the discontinuation of these ITAC member-incentive programs that required certification for eligibility.

[24] The SWCC is now the ICC–SWCC.

Another driver for small wind certifications is the IRS requirement for the small wind Business Energy ITC (IRS 2015). The extension of the ITC, as described in Section 4.1.2, may continue to motivate small wind turbine manufacturers to pursue certification.

During the Distributed Wind Energy Association Business Conference in February 2023, multiple turbine manufacturers announced their intent to certify their turbine models. Eocycle Technologies, Inc. is expected to initiate the certification process for its EOX M-series turbine model in September 2023. Sonsight Wind intends to start the certification process for its 3.5-kW turbine model by the end of 2023. Primus Wind Power will recertify its six microturbine models to the new ANSI/ACP 101-1 standard with CIP support (Laurie 2022). In addition, HI-VAWT reported through direct communications with the PNNL team that it hopes to get the certification process of its 25-kW turbine model back on track after pandemic disruptions.

5 Installed and Operations and Maintenance Costs

PNNL collected the cost data presented in this section from state and federal agencies, project owners and developers, installers, and news reports, as described in Appendix B.

5.1 Small Wind Installed Costs

Figure 11 presents the average annual and project-specific small wind installed costs (in 2022 dollars) for 2013 through 2022. Figure 11 only includes projects with reported installed costs that use turbines with known rated capacities[25] and only includes an annual average for years in which there are three or more reported projects.[26]

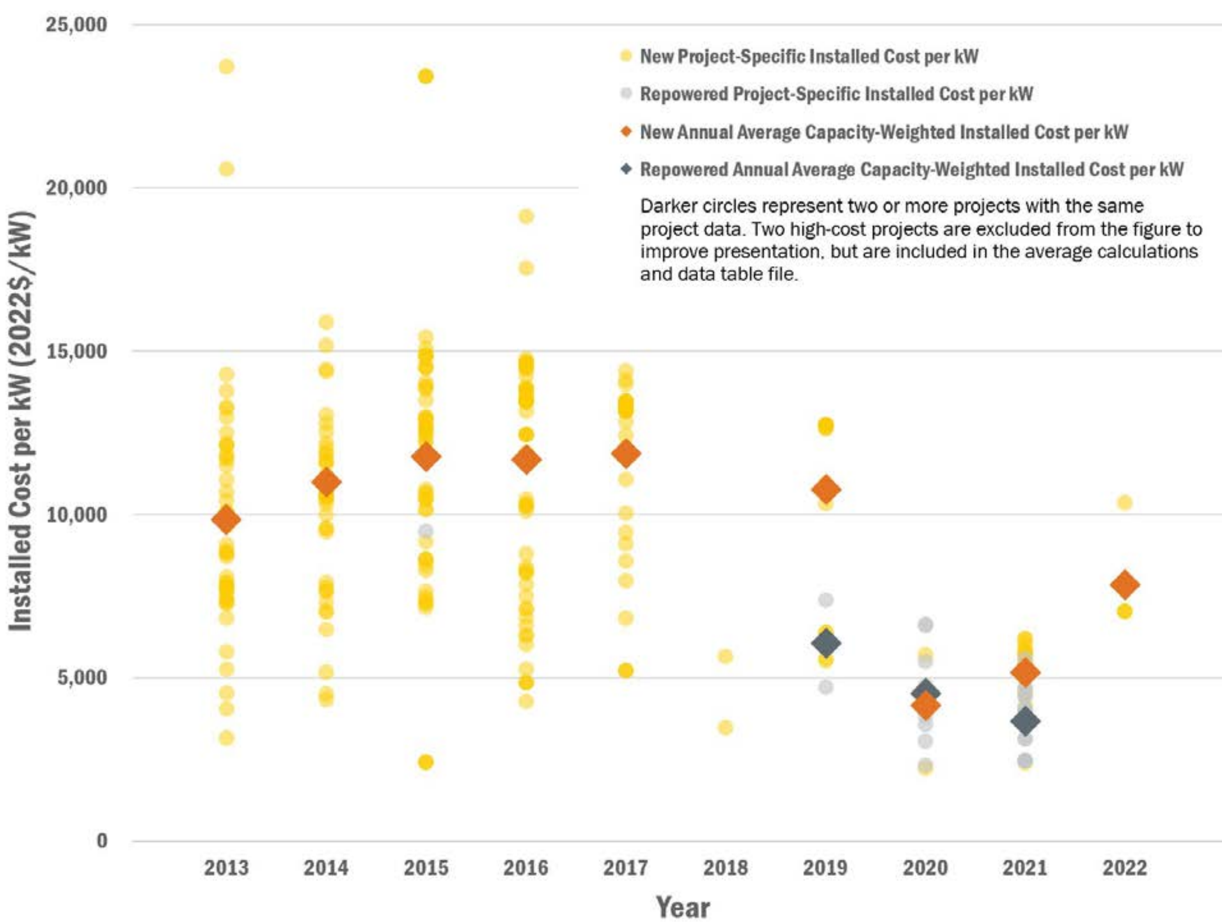

Figure 11. Annual average and project-specific new and repowered small wind installed project costs, 2013–2022

The overall average capacity-weighted installed cost for new small wind projects from 2013 through 2022 was $10,670/kW. Of the small wind projects installed in 2022, the PNNL team was only able to obtain cost reports for four of the projects. The average capacity-weighted installed cost for these projects was $7,850/kW based on the four projects using five wind turbines in two states with a combined rated capacity of 78 kW. The limited sample sizes in PNNL's dataset for reported costs in 2018, 2020, and 2022, along with high variance in

[25] See Table B.1 in Appendix B for the small wind turbine models included in this analysis.
[26] Figure 11 excludes two high-cost projects, one in 2014 at $41,544/kW and one in 2016 at $32,390/kW, to improve visibility of the data, but those projects are included in the average calculations presented and in the data table file.

distributed wind project costs, have prevented the PNNL team from being able to clearly identify any cost trends for small wind turbine installations over time.

The installed cost amount includes the wind turbine equipment costs, or the hardware costs, as well as the balance-of-station costs. Balance-of-station costs[27] can typically represent up to 60% of a new small wind project's total installed cost and therefore play a significant role in overall small wind installed costs (Orrell and Poehlman 2017). The varying sample sizes and the high variance in project-specific costs contributes to the cost ranges exhibited each year.

Average annual (when available) and known project-specific small wind installed costs for repower projects (in 2022 dollars) are also shown in Figure 11. Installers did not share any costs for repowered small wind projects in 2022, but repower projects generally tend to be less expensive than new installations, as shown in Figure 11. For 2019 through 2021, the overall average capacity-weighted installed cost for small wind repowers was $4,750/kW. The use of refurbished turbine units is common in repowers. Refurbished turbines represent the low end of the installed cost ranges for repowered projects.

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

Figure 12 presents the average annual and project-specific costs (in 2022 dollars) for projects using turbines greater than 100 kW for years 2013 through 2022. Figure 12 only includes projects with reported installed costs and only includes an annual average for years in which there are three or more reported projects.

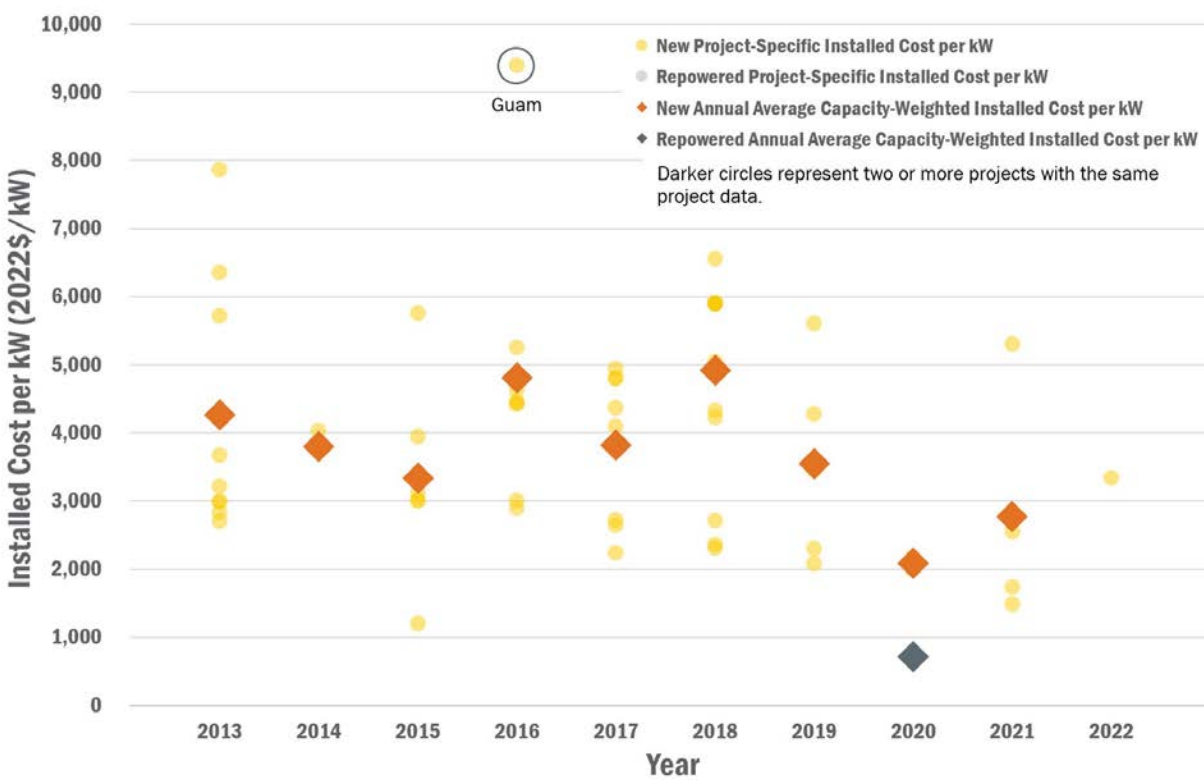

Figure 12. Annual average and project-specific new and repowered installed costs for projects using turbines greater than 100 kW, 2013–2022

[27] The balance-of-station costs of a distributed wind system include customer acquisition and qualification; installation, foundation, and electrical labor, materials, and equipment; transportation; taxes; zoning, permitting, inspection, interconnection, and incentive labor and fees; engineering and design (e.g., site assessment, foundation design, and geotechnical report); financing; and overhead and profit (Forsyth et al. 2017).

The availability of cost information for distributed wind projects using turbines greater than 100 kW varies from year to year. The PNNL team documented four distributed wind projects using turbines greater than 100 kW for 2022, but only one of them had a reported installed cost, as shown in Figure 12; therefore, no average cost was calculated for 2022. The overall average capacity-weighted installed cost for projects using turbines greater than 100 kW for the period of 2013 through 2022 is $4,050/kW. As with small wind projects, large-scale repower projects, especially those utilizing refurbished turbines, can be less expensive than new installations, as highlighted by the year 2020 in Figure 12. The average installed cost of the 12 retrofit projects using the same refurbished midsize turbine model in 2020 was roughly $700/kW.

Because of the annual variations in data availability, the average costs reported for each year likely contain bias because of the project sample-size variation (e.g., military projects with higher costs due to specific regulatory and cybersecurity requirements may dominate one year's sample, while lower-cost agricultural projects in Minnesota may dominate another year's sample). The outlier project circled in Figure 12 is installed in Guam. Higher installation costs in Guam are expected because of its remoteness, but the distributed wind energy also displaces higher electricity costs (compared to the continental United States), so the project is still cost effective.

5.3 Operation and Maintenance Costs

The term O&M costs is common; however, operation costs differ from maintenance costs and not all distributed wind projects experience them equally. O&M activities can be performed by project owners or outsourced to third-party service providers. 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, but they are not typically substantial, or even present, for small distributed wind projects, primarily because the turbine owner and the landowner are one and the same. On the other hand, all wind projects, distributed or otherwise, require maintenance.

For a large distributed wind project, O&M costs of the turbine system are part of the project's total operating expenses. The Land-Based Wind Market Report, which concentrates on utility-scale wind farms and wind turbines that exceed 100 kW in size, reports that O&M costs for 83 projects installed since 2010 have averaged about $20/kW/year and that O&M costs can be less than half of total operating expenses (Wiser and Bolinger 2023).

Maintenance costs can be categorized as scheduled or unscheduled. Scheduled maintenance activities for small wind projects can include inspecting the turbine, controller, and tower; adjusting blades; checking the 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 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.

For small wind, in most cases, the project installer or developer performs the maintenance for the small wind turbine 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. The average scheduled maintenance cost per visit for small wind is about $37/kW (Orrell and Poehlman 2017). This is in line with other data that suggest operation and maintenance costs for distributed wind projects are typically $35/kW/yr (NREL 2022b).

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.[28] This section looks at capacity factors in various ways to evaluate the performance of distributed wind turbines.

6.1 Small Wind Capacity Factors

Figure 13 presents the calculated capacity factors, arranged by geographic region, for a sample of small wind projects that produced energy in 2022.[29] A box-and-whisker plot was selected to provide visibility into the average, median, and extreme capacity factors in each region. The small wind annual generation data used in the capacity factor calculations are from turbine monitoring web portals and generation data reports shared with the PNNL team from turbine owners, manufacturers, and operators and include 101 turbines totaling 1.4 MW in rated capacity and ranging in rated capacity from 2.1 kW to 90 kW installed from 2009 through the beginning of 2022. Of the 101 turbines, the PNNL team had the metadata available to classify 69 into geographic regions. The remaining 32 have unknown locations.

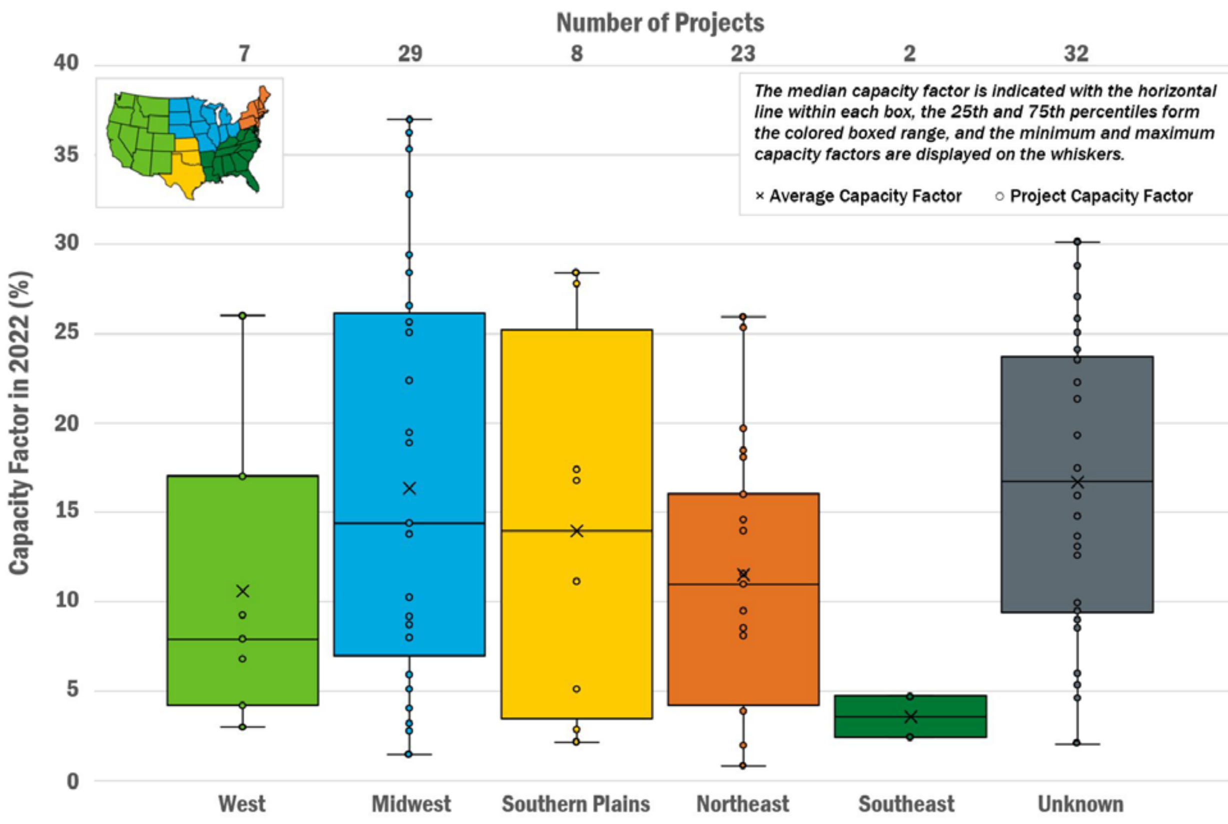

Figure 13. Small wind capacity factors in 2022

[28] Capacity factor calculations for small wind 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.

[29] With the intent to provide an accurate portrayal of actual wind turbine production (including losses and downtime) in 2022, the following data-quality-control guidelines were applied. Turbines with a full 12 months of reported data were included in the analysis. In addition, turbines with missing data were included if they were off-line or had missing data (1) during the middle of 2022, (2) at the beginning of 2022 if those turbines had been online and reporting prior to 2022, or (3) at the end of 2022 if they came back online in 2022. Turbines were excluded from the analysis if they first came online during 2022 or if they were off-line or missing data at the end of 2022 into 2023 (as this could indicate decommission). PNNL does not know the reasons turbines were off-line or missing data. This methodology also applies to Figure 14 and Figure 15.

The overall average capacity factor in 2022 for these small wind projects was 15%. The seven small wind projects in the West yielded an average 2022 capacity factor of 11%. The 29 small wind projects in the Midwest produced the highest 2022 capacity factors, with an average of 16% and three projects that exceeded 35%. The eight small wind projects in the Southern Plains yielded an average 2022 capacity factor of 14%. The 23 small wind projects in the Northeast, the majority of which are in New York, yielded an average 2022 capacity factor of 12%. New York's high electricity prices and past available incentives enabled significant small wind capacity additions for many years, despite the state's relatively low wind resource. The two small wind projects in the Southeast, the region with the lowest wind resource in the United States (WINDExchange 2023), produced the lowest 2022 capacity factors, with an average of 4%. And the 33 small wind projects with unknown locations yielded an average 2022 capacity factor of 17%.

The wide range of observed small wind capacity factors, from 1% to 37%, reflects, among other variables, the assessment and siting challenges for small wind. The same turbine model sited in different locations can achieve very different capacity factors, due to differences in the local wind resource and turbulence created by nearby obstacles and complex terrain. In addition, low turbine availability due to a turbine not operating for extended periods because of mechanical problems or other reasons, can lower the turbine's overall capacity factor. Poor measuring and reporting of energy production may also be factors.

6.2 Capacity Factors for Projects Using Turbines Greater Than 100 kW

The annual generation data for projects using wind turbines greater than 100 kW, and at least 1 MW in size, are from Energy Information Administration (EIA) Form 923 reports. Wind projects with a total size of at least 1 MW are required to report net annual energy generation to the EIA (EIA 2023a). From these records, PNNL identified 27 distributed wind projects installed from 2005 to 2018, across 14 states, totaling 95 MW in combined capacity that reported generation amounts for 2022. Turbine nominal capacities used in the projects range from 600 kW to 3 MW, but the project size may be larger since some projects are composed of multiple turbines. Figure 14 presents the calculated capacity factors in 2022, arranged by geographic region and by turbine size, for these projects using turbines greater than 100 kW.

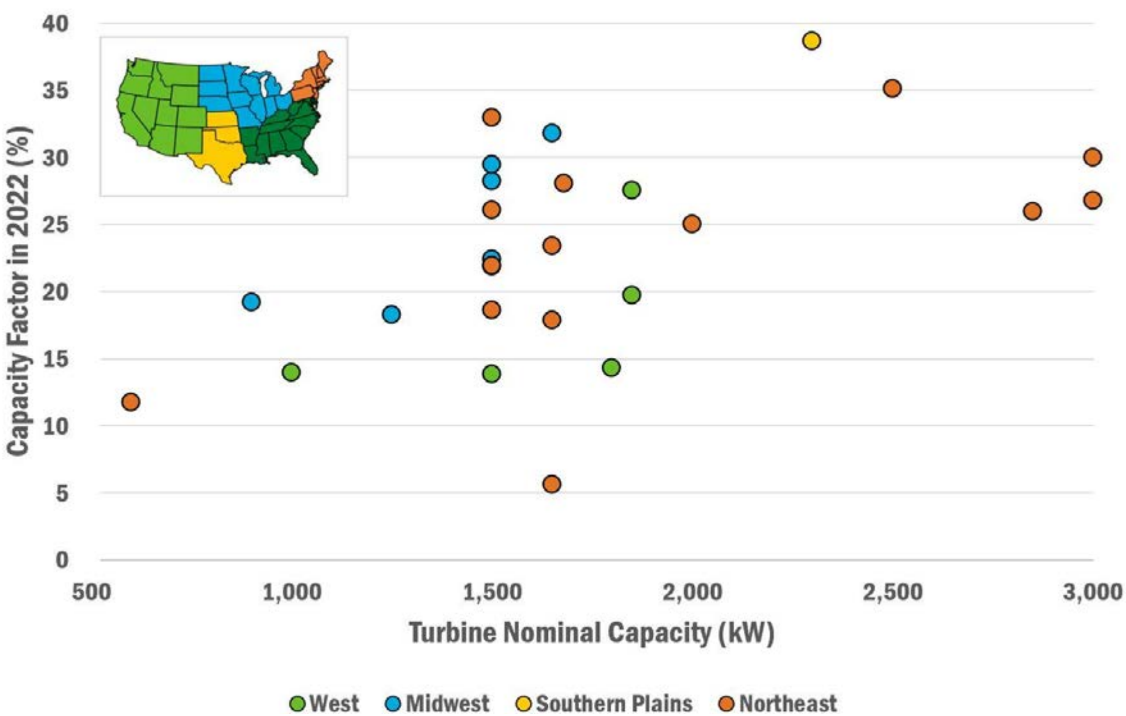

Figure 14. Capacity factors in 2022 for projects using turbines greater than 100 kW

The wind projects in Figure 14 exhibit a wide range of observed capacity factors, from 6% to 39%. The average capacity factor in 2022 for projects using turbines greater than 100 kW is 23%. The average capacity factor in 2022 for projects using turbines greater than 100 kW is eight percentage points larger than the average 2022 capacity factor for projects using small wind turbines (15%). This is most likely because large-scale turbine projects typically have thorough wind resource assessments as part of the siting process (to achieve optimal energy generation), undergo routine maintenance (to sustain high levels of reliability), and have taller hub heights (to capture higher wind speeds).

Geographically, the average capacity factors in 2022 for the Midwest, Northeast, and West are 25%, 23%, and 18%, respectively. The single project in the Southern Plains, a region noted for its strong wind resource (WINDExchange 2023), produced the highest capacity factor in 2022 of 39%.

6.3 Annual Capacity Factor Comparison

To assess distributed wind performance in 2022 relative to the previous year, Figure 15 provides capacity factors for 2021 compared to 2022 for projects using small, midsize, and large wind turbines across the continental United States. Projects near the dashed line in the figure indicate the project had similar performance in 2021 and 2022. Projects above the dashed line correspond to higher generation in 2022 than in 2021. Projects below the dashed line had higher generation in 2021 than in 2022.

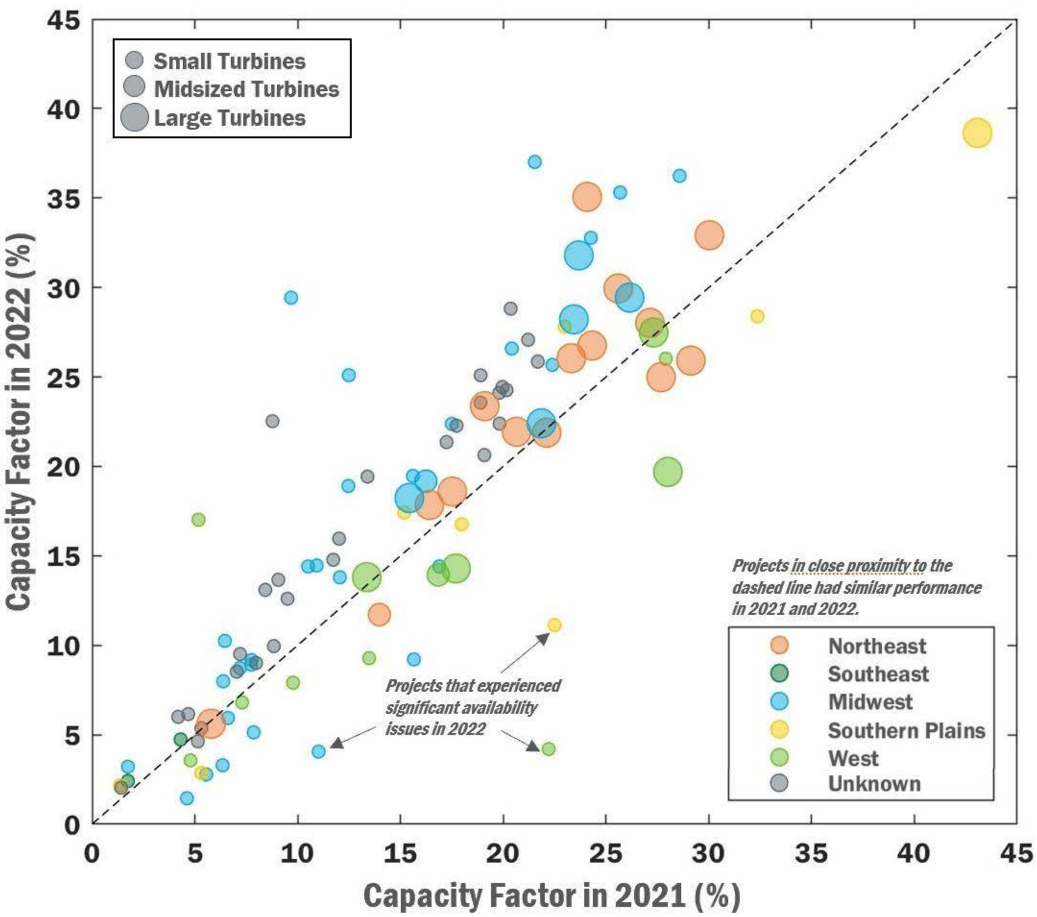

Figure 15. Distributed wind capacity factors, 2021-2022

Of the 122 projects for which PNNL had generation data for 2021 and 2022, 73 of projects (60%) had higher capacity factors in 2022 than in 2021 by at least one percentage point. A total of 28 projects underperformed in 2022 relative to their capacity factors in 2021 by at least one percentage point and the remaining 21 projects performed similarly between the two years. Across the projects, the average capacity factor in 2021 was 14% and the average capacity factor in 2022 was 16%.

Differences in annual distributed wind performance occur for a variety of reasons, including the project's available wind resource, turbine availability (i.e., downtime for expected or unexpected maintenance), and site changes (i.e., building construction or vegetation growth). Several small wind projects experienced availability issues in mid-2022 which strongly impacted their performance relative to the prior year, including a California residential project that went from a 22% capacity factor in 2021 to 4% in 2022, a Kansas agricultural project that went from 22% in 2021 to 11% in 2022, and an Ohio residential project that went from 11% in 2021 to 4% in 2022 (Figure 15).

Distributed wind performance in 2022 relative to 2021 varied significantly according to geographic region. In the Midwest, 25 projects produced capacity factors in 2022 that exceeded their performance in 2021, while two projects were consistent between the years and seven projects underperformed. The average Midwest capacity factors in 2021 and 2022 were 14% and 18%, respectively. Several projects in the Midwest outperformed substantially in 2022 relative to 2021, including two agricultural small wind projects in northwestern Iowa that outperformed by 15 and 20 percentage points.

The interannual wind resource played a noticeable role in distributed wind performance trends between 2021 and 2022, particularly in the Midwest. Figure 16 displays the ratio of the 2022 to 2021 annual average wind speed over the continental United States from the ERA5 model.[30] In the Midwest, 2022 was a stronger wind resource year than 2021, corresponding with the trend identified for Midwestern distributed wind performance where generation in 2022 exceeded generation in 2021 (Figure 15). Both years 2021 and 2022 were in the La Niña phase of the El Niño-Southern Oscillation climate pattern, with 2022 producing slightly stronger La Niña indices (Climate Prediction Center 2023). Typical La Niña patterns tend to produce an active storm track, with associated stronger winds, in the Northern Plains and Upper Midwest (National Weather Service 2023).

Conversely, in the West, only one project outperformed in 2022 relative to 2021, while three projects were consistent between the two years and eight projects underperformed by up to 18 percentage points. The average capacity factors in the West in 2021 and 2022 were 16% and 14%, respectively. Figure 16 shows lower wind resource in the West in 2022 versus 2021, particularly in the Pacific Northwest.

Like the Midwest, most projects (20 out of 38) in the Northeast outperformed in 2022 relative to 2021, but not as overwhelmingly, as ten projects in the region performed consistently and eight projects underperformed within five percentage points. The average Northeast capacity factors in 2021 and 2022 were 15% and 16%, respectively. Similar to the performance trend, the wind resource in 2022 in the Northeast tended to be similar to or above the wind resource in 2021.

In the Southern Plains, two projects outperformed in 2022 relative to 2021, one project performed consistently, and five projects underperformed. The average Southern Plains capacity factors in 2021 and 2022 were 20% and 18%, respectively. Several of the small wind projects in the region were impacted by more availability events in 2022 than in 2021. The wind resource in 2021 and 2022 in the Southern Plains was similar.

[30] The European Centre for Medium-Range Weather Forecasts Reanalysis 5th Generation, commonly referred to as ERA5 (ECMWF 2023). The reanalysis model provides decades-long wind resource data at an hourly resolution.

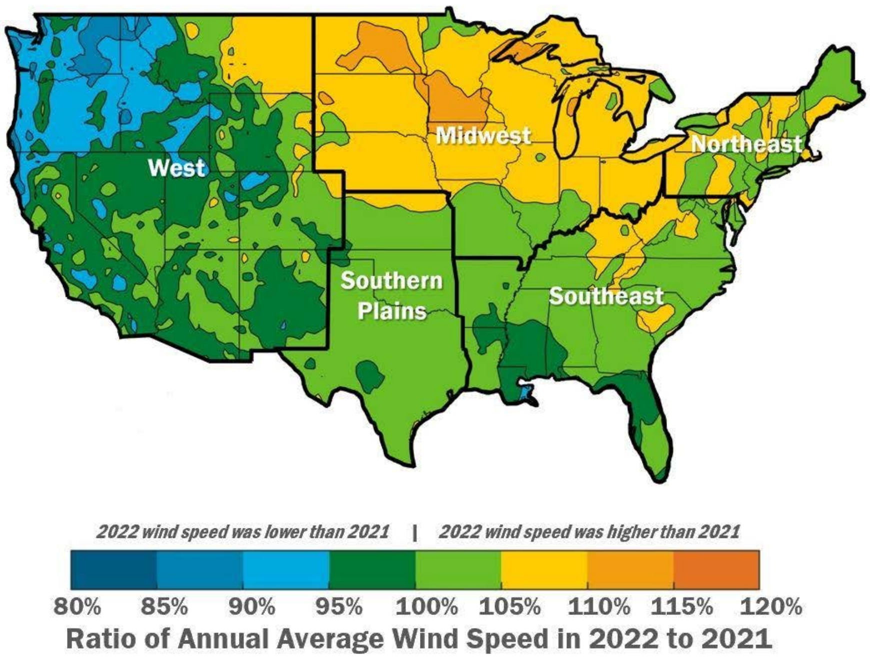

Figure 16. Wind resource map, 2021-2022

The two small wind projects in the Southeast performed similarly in 2021 and 2022, with capacity factors below 5%. The consistent interannual performance of one project, located in south central Florida, aligns with the consistent interannual wind resource trend in this area. The consistent interannual performance of the second project, located in central Kentucky, is misaligned with the modeled wind resource data, which indicates that 2022 was a better wind resource year than 2021 at this location. In 2022, however, the Kentucky turbine experienced availability issues that did not occur in 2021, likely offsetting the advantageous wind resource of 2022 and resulting in similar performance between the two years.

It is interesting to note that distributed wind projects using large turbines, which tend to experience less availability issues than small turbines due to the degree of investment leading to increased resources for O&M support, particularly follow the regional wind resource trends. All Midwest projects using large turbines outperformed in 2022 relative to 2021. Most Northeast projects using large turbines outperformed in 2022, and those that did not, consistently performed or only slightly underperformed. No projects using large turbines in the west outperformed in 2022 relative to 2021. The single Southern Plains project using large turbines underperformed in 2022 by four percentage points, while still achieving a capacity factor of 39%, which is the average utility-scale wind capacity factor for recently built projects (Wiser et al. 2022).

7 Levelized Cost of Energy

Levelized cost of energy (LCOE) represents the present value of all anticipated project costs (installed and O&M) divided by 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.

The LCOE for a wind project owner can be reduced by either decreasing the initial capital costs (the numerator of the equation) or increasing its energy generation (the denominator of the equation) while not disproportionately increasing costs. With the stackable bonus credits available in the extended Business Energy ITC and a grant from USDA REAP, rural small business owners or farmers could significantly reduce their upfront capital costs for distributed wind and thus achieve lower LCOEs.

Past market reports have reported estimated LCOE for distributed wind projects using performance and cost data reported from the EIA, USDA REAP, and NYSERDA with NREL's LCOE method and assumptions detailed in Appendix B (NREL 2020). To calculate LCOE estimates, the PNNL team must have access to at least a full year of energy production data for a project as well as an installed cost report for it. The number of projects for which the PNNL team has both installed cost reports and production data is limited. As a result, the team has not calculated any LCOE estimates from empirical data for this report and will continue to consider the best ways to calculate and present LCOE estimates in future reports as more new and relevant data become available.

The NREL *2021 Cost of Wind Energy Review* presents modeled small wind LCOE estimates that are generally in line with past market report empirical-based estimates (Stehly and Duffy 2022). For a representative 20-kW installation, the estimated LCOE was 14.3¢/kWh in 2021 dollars without including any incentives that would lower the capital cost. For a representative 100-kW installation, the LCOE, without any incentives, was estimated at 9.4¢/kWh.

Whether or not a distributed wind project's LCOE is cost competitive with retail electricity rates depends on the location of the site, as retail rates vary greatly across the United States. According to the EIA, average U.S. retail electricity rates, which small wind turbines are most likely to displace, range from around 10¢ to 34¢/kWh for residential customers and from around 8¢ to 24¢/kWh for commercial customers (EIA 2023b). Hawaii, Alaska, Puerto Rico, the U.S. Virgin Islands, Guam, and the Northern Mariana Islands have higher rates, making distributed wind potentially more cost competitive in those areas, even when project costs for those locations are also likely to be higher.

8 Distributed Wind Markets

This section details customer, interconnection, wind turbine size, and tower characteristics of distributed wind sales and installations.

8.1 Customer Types

Customers install distributed wind for several reasons, including to increase energy security, lower utility bills, hedge against future energy price increases, mitigate energy price volatility, or generate renewable energy to help meet decarbonization goals. A distributed wind project can either be owned directly by the end-use customer or the end-use customer can purchase energy produced by a distributed wind project.

This report considers seven main customer types for distributed wind: (1) utility, (2) residential, (3) institutional, (4) government, (5) commercial, (6) industrial, and (7) agricultural.

1. Utilities can be investor owned, publicly owned,[31] tribal owned, or rural electric cooperatives.
2. Residential applications include remote cabins, private boats, rural homesteads, suburban homes, and multifamily dwellings.
3. Institutional applications are for entities that are typically non-taxed and mainly consist of schools, universities, churches, nonprofits, and local unions.
4. Government applications are also projects for non-taxed entities such as federal agencies, states, cities, municipal facilities (e.g., water-treatment plants and fire departments), military sites, and tribal governments.
5. Commercial applications include offices, car dealerships, retail spaces, restaurants, telecommunications sites, and distribution centers.
6. Industrial applications are facilities that manufacture goods, perform engineering processes, or engage in extractive activities (e.g., food processing plants, appliance manufacturing plants, oil and gas operations, and mines).
7. Agricultural applications include all types of farms, ranches, and farming operations (e.g., nurseries and vineyards).

Agricultural and residential end-use customers, which typically use small wind turbines, usually account for most of the distributed wind installations by number of projects, while projects using large-scale turbines that serve utility customers have consistently accounted for the majority of distributed wind capacity. In 2022, projects for agricultural customers accounted for 33% of the number of all projects installed. Residential and commercial customers each represented 26% of installed projects, utility customers represented 10%, and industrial and institutional customers each represented just under 3% of installed projects.

Distributed wind deployed for utility customers represented the largest share of total distributed wind capacity installed in 2022, accounting for 78% of the documented capacity, compared to 55% in 2021 and 54% in 2020. Industrial customers represent the second largest percentage of distributed wind capacity installed in 2022, accounting for 20% of capacity installed compared to 25% in 2021 and 34% in 2020. Three out of four of the projects using large-scale wind turbines were for utilities and one project was for an industrial customer. Distributed wind for agricultural, residential, commercial, institutional, and government customers each accounted for 1% or less of the distributed wind capacity installed in 2022.

[31] Publicly owned utilities can be municipalities or other, non-city types of public power ownership.

Institutional and government customers have typically represented a smaller number of projects, as well as total percentage of project capacity. Government projects include wind turbines for military operations, municipal water systems, prisons, parks, and tribal governments. Most institutional customers are schools, including colleges and universities, but wind turbines have also been deployed at local unions and religious establishments.

Figure 17 shows the breakdown of customer types by number of projects for 2014–2022, and Figure 18 shows the breakdown of customer types by distributed wind capacity for 2014–2022.

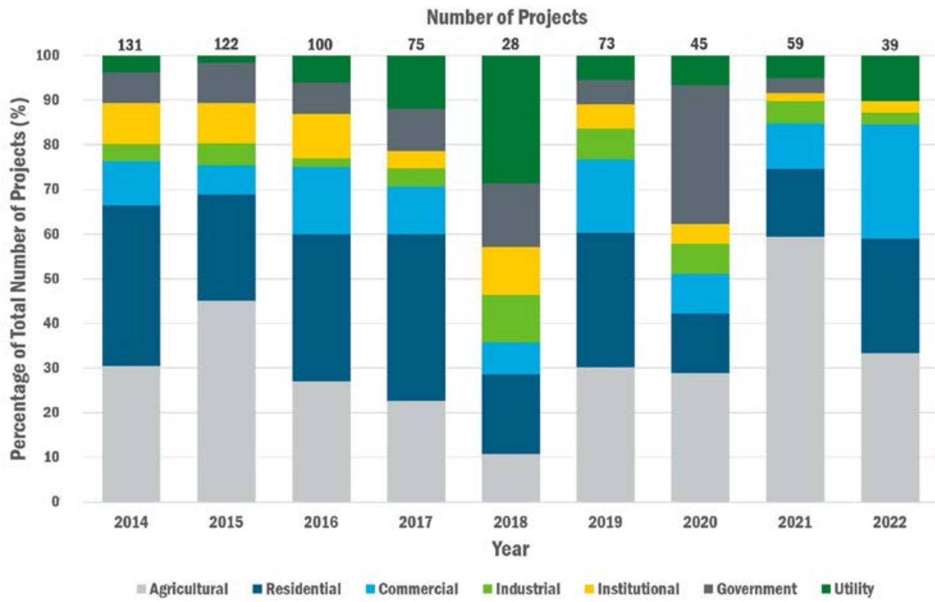

Figure 17. Distributed wind end-use customer types by number of projects, 2014–2022

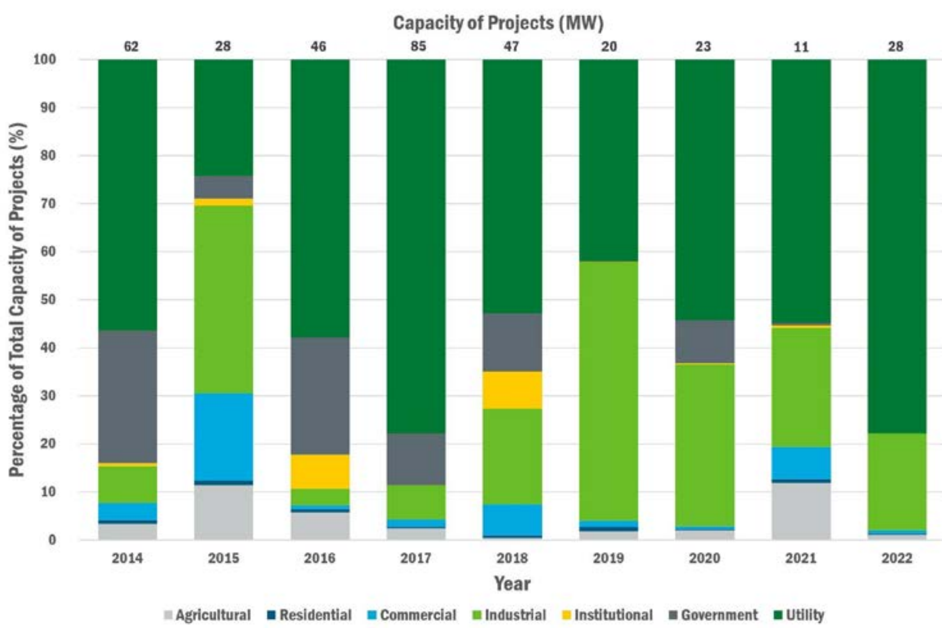

Figure 18. Distributed wind end-use customer types by capacity of projects, 2014–2022

8.2 Interconnection Types

This report tracks two primary interconnection types for distributed wind: on-site use (i.e., behind-the-meter, remote net-metering, grid-connected microgrid, and off-grid applications) and local use (i.e., load-serving distribution line and isolated grid applications). In 2022, 90% of the distributed wind projects were deployed to provide energy for on-site use and 10% of projects were interconnected to a distribution grid to provide energy for local use, as shown in Figure 19. The projects for on-site use account for 22% of the deployed distributed wind capacity in 2022 while 78% of the capacity was from projects providing energy for local use, as shown in Figure 20.

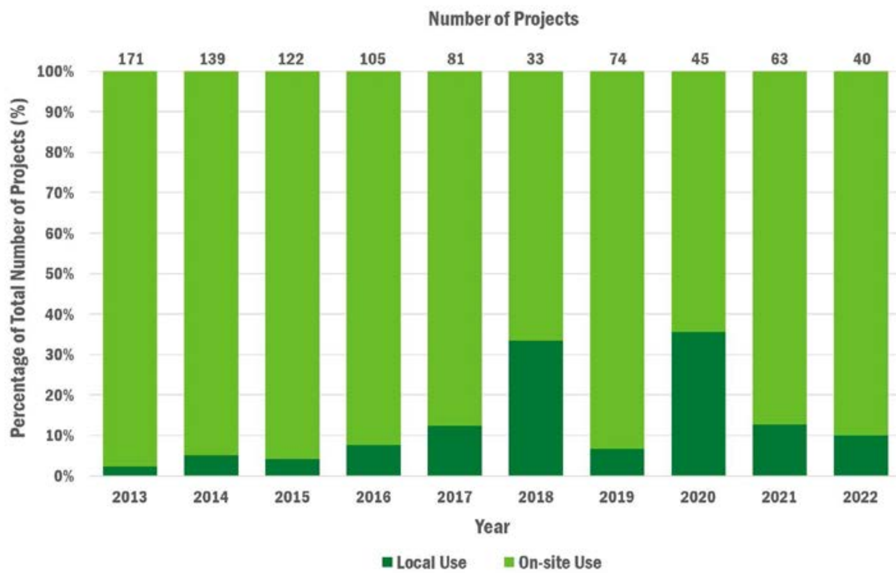

Figure 19. Distributed wind for on-site use and local loads by number of projects, 2013–2022

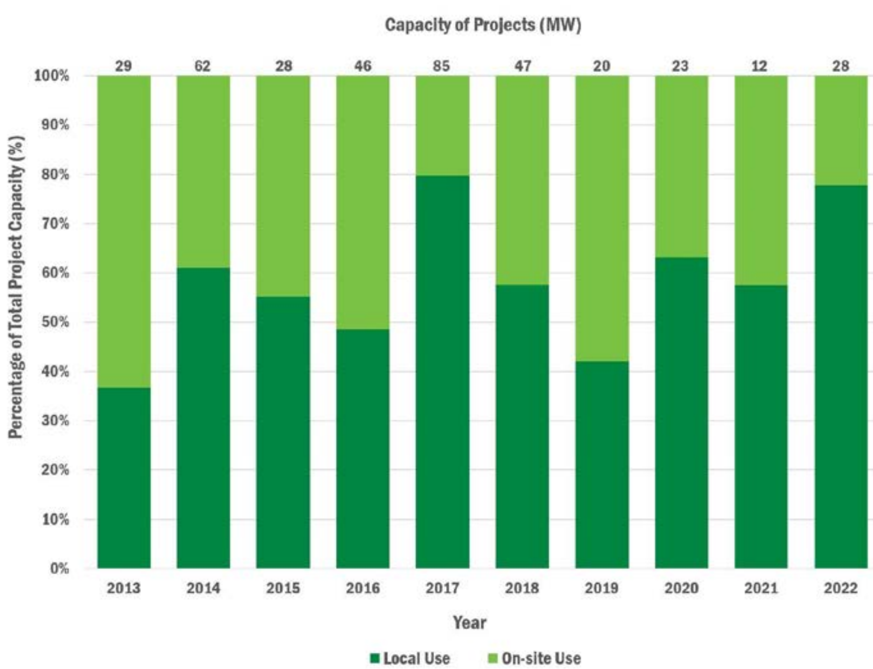

Figure 20. Distributed wind for on-site use and local loads by capacity of projects, 2013–2022

Distributed wind can serve on-site energy needs in various applications. The three most common on-site interconnection categories are behind-the-meter installations used to offset a portion of energy costs for grid-connected customers, grid-connected microgrids, and off-grid installations used to power remote locations not connected to the local distribution grid.

Most distributed wind projects for on-site consumption are behind-the-meter installations for rural or suburban homes, farms, schools, and manufacturing facilities. In 2022, 100% of all on-site use projects were deployed as behind-the-meter installations. A behind-the-meter wind turbine is connected to the local distribution grid behind the customer's utility meter and may provide excess generation to the distribution grid through net-metering or other billing mechanisms. Distributed wind projects for on-site use are also in grid-connected-microgrids, off-grid installations, and remote net-meter installations. About 4% of the distributed wind capacity (14.2 MW) deployed for on-site use in the PNNL team's master project dataset are in grid-connected microgrids and about 6% of the on-site use capacity is remote net-metered.

Off-grid small wind turbine models account for the bulk of wind turbine units deployed in U.S. distributed wind applications, but mainly because the PNNL team only tracks off-grid projects opportunistically, they account for a tiny fraction of the on-site use capacity documented in the dataset. An estimated 94% of turbine units deployed in 2022 in distributed wind applications were to charge batteries or power off-grid sites (e.g., remote homes, oil and gas operations, telecommunications facilities, boats, rural water or electricity supply, and military sites). This compares to 96% in 2021 and 97% in 2020.

While most distributed wind projects are interconnected for on-site use, projects for local use represent more of the installed distributed wind capacity due to the projects' larger sizes and use of larger turbines. Distributed wind for local use is connected to the distribution grid to serve loads interconnected to the same distribution grid. This type of project is typically referred to as a front-of-meter installation. Front-of-meter wind projects typically include multiple turbines greater than 100 kW in size, and often, greater than 1 MW in size. The distribution grid can be connected to a larger transmission system or be an isolated grid. Isolated grids are common in remote areas of Alaska. About 4% of the distributed wind capacity (24 MW) deployed for local use in PNNL's master project dataset are in isolated grids while the rest is in front-of-meter installations on distribution systems connected to transmission systems.

8.3 Wind Turbine Sizes

Because the distributed wind market is not uniform, this report analyzes the market from different perspectives, including by turbine size and customer type. Different factors are at play for each turbine size segment, in part because some turbine sizes are more applicable for certain customer applications than others.

Large-scale turbines dominate the amount of distributed wind capacity installed annually because of their higher capacity. As the number of customers using higher-capacity large-scale turbines has increased, so has the average nameplate capacity of turbines greater than 100 kW in distributed wind projects, as shown in Figure 21. In 2003, the average turbine capacity used in distributed wind projects with turbines greater than 100 kW in size was 1 MW. In 2018, the average capacity size was 2.2 MW—just more than double the capacity of turbines used in 2003. The trend was disrupted, because of a bump in midsize turbine deployment in 2021 and 12 midsize turbine repowers in 2020, before restarting in 2022. The average size of turbines greater than 100 kW in distributed wind projects in 2022 was 2.7 MW.

Most distributed wind projects are single-turbine projects, so a significant variation between average project size and average turbine size in a given year indicates that the dataset sample includes multi-turbine projects. The four projects installed in 2022 represented in Figure 21 use GE 2.82-MW and GE 2.3-MW wind turbines and thus push the average project size to the highest it has been and push back up the average turbine size.

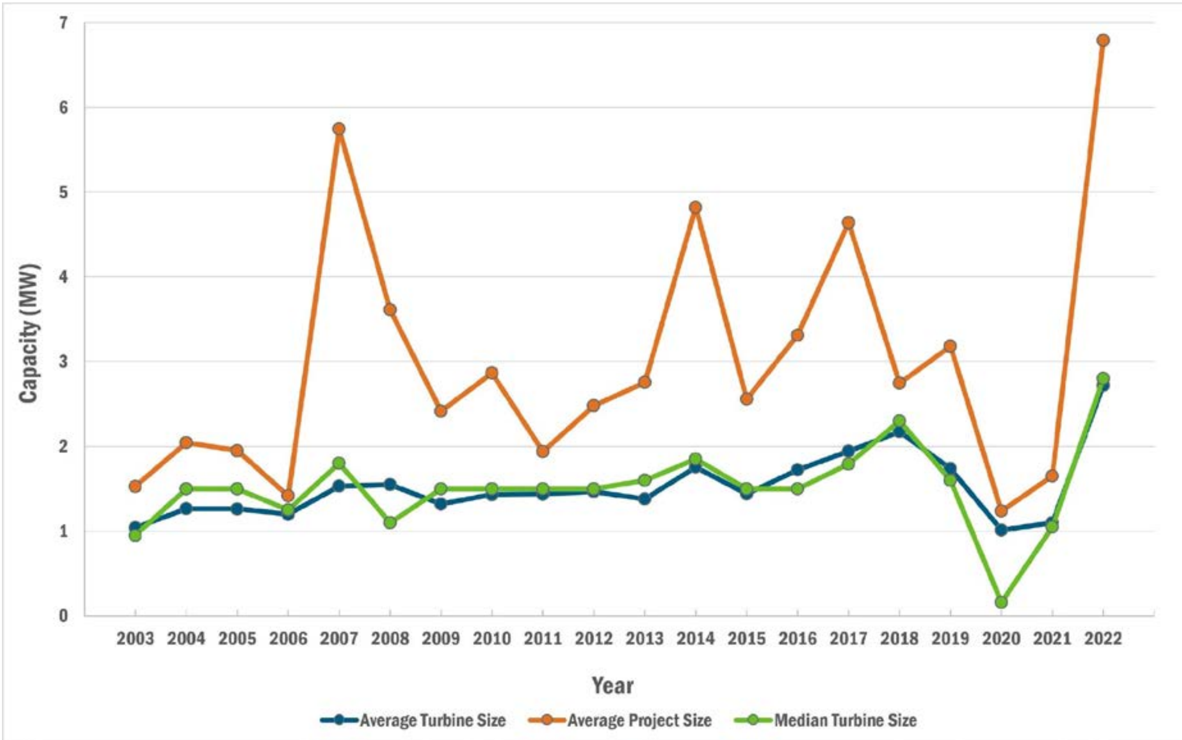

Figure 21. Average size of turbines greater than 100 kW in distributed wind projects and average size of those projects, 2003–2022

Figure 22 shows the annual small wind capacity additions by turbine size, and Figure 23 shows the percentage of capacity additions by turbine size. The less-than-1-kW size segment represents 21% of the small wind capacity sold in 2022 with 0.5 MW. The size segment of 1–10 kW represents 4% with 0.1 MW. And the size segment of 11–100 kW (new and refurbished) represents 75% with 1.7 MW.

There is typically noticeable year-to-year variation in the size segments. While unit sales of the less-than-1-kW turbine size increased from 2021 to 2022, the size segment represents slightly less of the overall small wind capacity in 2022 than it did in 2021 because of a significant increase in turbine sales in the size segment of 11–100 kW. In 2022, there were a reported 80 turbine units for a total of 1.7 MW sold in the size segment of 11–100 kW compared to 45 units for a total of 1 MW in 2021. And as Bergey Windpower has increased production of its Excel 15 turbine model, its sales of the Excel 10 model have decreased, accounting for some of the drop in capacity from 2021 to 2022 in the size segment of 1–10 kW. Other reasons for variation can include inconsistent sales due to changing market conditions and turbine manufacturer business operations. The single-year presence of a given manufacturer can significantly affect overall small wind sales capacity. The upcoming market reentries of the Skystream 3.7 turbine model on the lower end of the small wind size range with a 2.4-kW nominal capacity and the NPS 100 turbine model at the top of the small wind size range with a 100-kW nominal capacity could reshape the segment representations in Figure 22 and Figure 23 in the coming years.

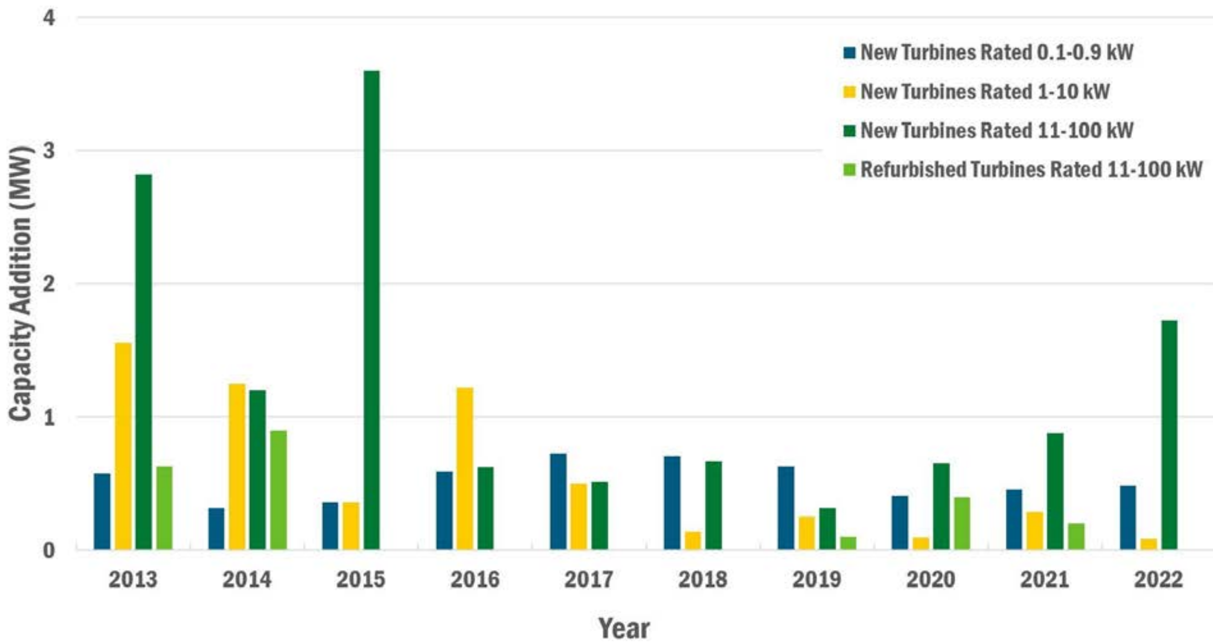

Figure 22. U.S. small wind sales capacity by turbine size, 2013–2022

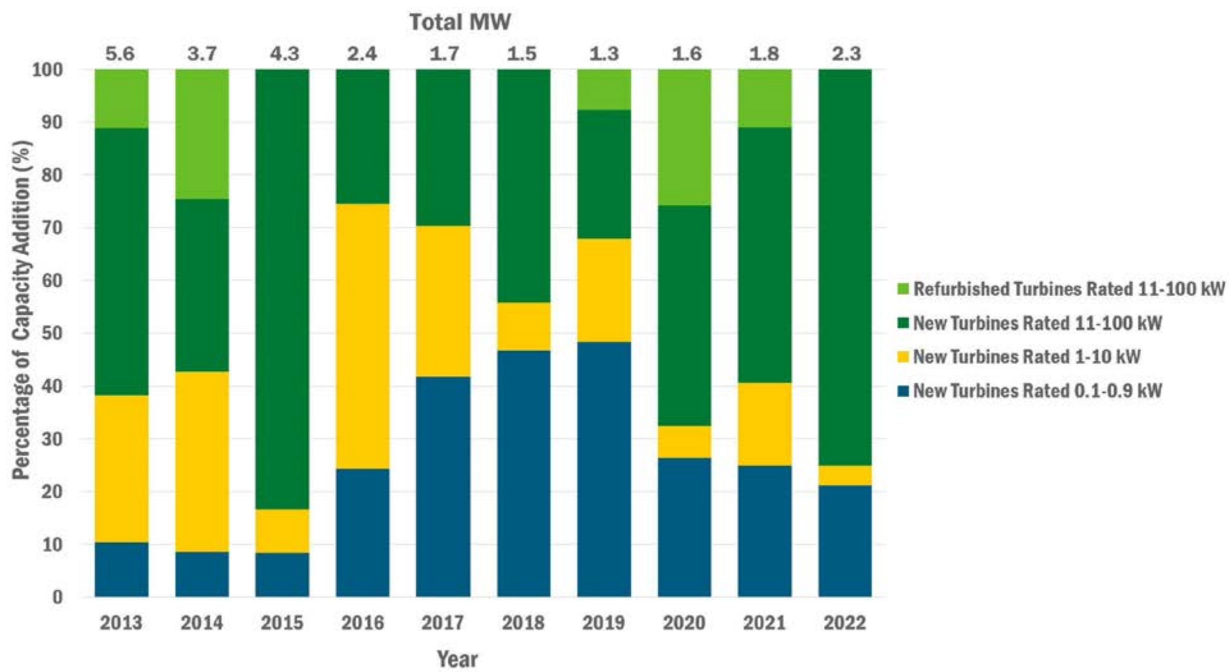

Figure 23. U.S. small wind sales percentage of capacity by turbine size, 2013–2022

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), some manufacturers who have historically responded did not respond this year and some were likely missed, particularly small wind vertical-axis wind turbine manufacturers. In 2022, vertical-axis wind turbine models (all less than 3 kW in nameplate capacity) account for 2% of the U.S. small wind turbine units sold. Vertical-axis wind turbine models accounted for about 1% of turbine units in both 2021 and 2020.

8.4 Type of Towers

From 2003 through 2022, the majority of documented distributed wind projects used self-supporting monopole (including tilt-ups) and self-supporting lattice towers, representing 43% and 41%, respectively, of projects that provided tower type information to PNNL. Self-supporting lattice towers are the most common in small wind projects, deployed in 49% of all small wind projects reporting tower information. Self-supporting monopole towers are predominantly used in projects with turbines greater than 100 kW, representing 97% of projects in this size category.

Of the 12 projects for which PNNL was able to collect tower type information in 2022, six small wind projects use self-supporting lattice towers, one small wind project uses a self-supporting monopole tower, and one small wind project is a rooftop installation. The four large-scale turbine projects use self-supporting monopole towers. For small wind projects installed in 2022, reported hub heights are 10 m, 24 m, and 31 m. All of the large-scale turbines installed in 2022 have hub heights of 89 m.

9 Future Outlook and Market Potential

The *Distributed Wind Energy Futures Study,* released in May 2022 by NREL and funded by WETO, determined that there is substantial economic potential for distributed wind (defined as a project with a positive rate of return). The 2022 baseline scenario economic potential was 919 GW for behind-the-meter installations and 474 GW for front-of-the-meter installations (McCabe et al. 2022).

The projections increase substantially to 1.7 TW for behind-the-meter applications and more than 4 TW for front-of-the-meter installations in the 2035 scenario that includes more policy support, namely an extension of the federal ITC, and relaxed siting conditions. With the IRA's extension of the existing ITC and provision for the future Clean Energy ITC, the distributed wind industry now does have that policy support.

Siting conditions are also being addressed. The economic potential estimate assumes the costs associated with permitting and zoning are streamlined, but current permitting and zoning challenges are known to impede distributed wind adoption considerably (Orrell and Poehlman 2017). WETO is using funding appropriated through the Infrastructure Investment and Jobs Act of 2022 (enacted as Public Law 117-58 on November 15, 2021) to address deployment barriers associated with local zoning ordinances and permitting processes (WETO 2022).

The IRA and the Infrastructure Investment and Jobs Act provide significant funds (in the form of program funding, grants, loans, tax credits, and direct payments in lieu of tax credits) to advance clean energy technologies and decarbonize the economy, among many other initiatives. Based on past federal policy changes and the last significant infusion of federal funding into the clean energy industry, the distributed wind market could have significant growth within the next few years.

To illustrate, small wind sales in the United States peaked (within the 2003 to 2022 time period) in 2010 shortly after small wind turbines became eligible for the ITC in the Emergency Economic Stabilization Act of 2008 (enacted as Public Law 110-343 on October 3, 2008), as shown in Figure 24. Similarly, overall distributed wind capacity deployment peaked in 2012 following the American Recovery and Reinvestment Act of 2009 (enacted as Public Law 111-5 on February 17, 2009), which allowed cash payments (Section 1603 payments) in lieu of the ITC.

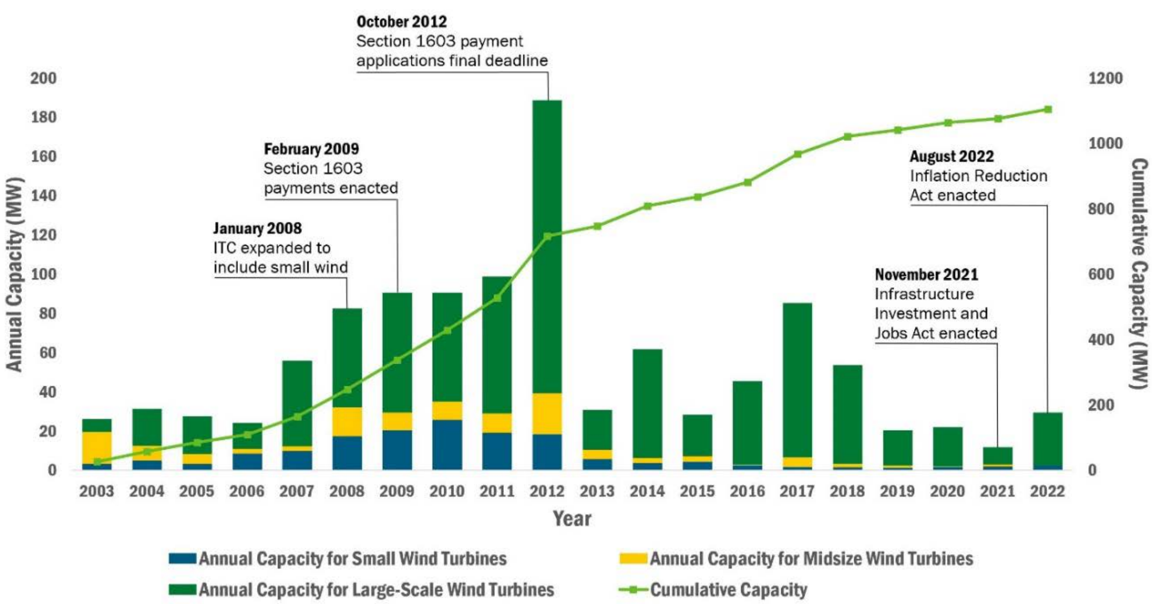

Figure 24. U.S. distributed wind capacity and federal policies, 2003-2022

However, there is no equivalent in the IRA to the broadly available Section 1603 payments, so future growth may be concentrated in specific market segments. For example, the increased UDSA REAP funding authorized by the IRA is available only to agricultural producers and rural small businesses and the direct-pay provision of the ITC under the IRA is limited to non-tax-paying entities.

10 Conclusions

This report documents trends and statistics for the U.S. distributed wind market. However, the market does not always exhibit consistent trends and there can be significant yearly variation with respect to customer demand, capital costs, incentive availability, technology changes and availability, regional wind resources, and deployment levels among and within the different turbine size segments (i.e., small, midsize, and large-scale).

Small wind sales increased from 2021 to 2022 with more new installations and fewer repowers than in 2021, while there were no midsize turbine deployments in 2022. Installed capacity from projects using large-scale turbines increased by more than double in 2022 from 2021. With the new program funding and tax credit opportunities available from the IRA and the Infrastructure Investment and Jobs Act, the distributed wind market is expected to grow, but this kind of variation is likely to continue considering the diverse ways in which distributed wind can be deployed.

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Appendix A: Wind Turbine Manufacturers and Suppliers

The small wind turbine manufacturers and suppliers listed in Table A.1 provided sales data for the listed models via the data-request process. Other small wind companies that provided information, or only had sales outside of the United States, are recognized in the Acknowledgments section. For the turbines greater than 100 kW in distributed wind projects included in the report and listed in Table A.2, the Pacific Northwest National Laboratory team reviewed the data sources described in Appendix B.

Table A.1. Small Wind Turbine Manufacturers and Suppliers

Manufacturer	Model Names	Headquarters
APRS World	WT10	Minnesota
Bergey Windpower Co.	Excel 10, Excel 15	Oklahoma
BE-Wind	EOW-200-ECO, EOW-200, EOW-300	Florida
Ducted Wind Turbines, Inc.	D3	New York
Eocycle Technologies, Inc.	EOX S-16, EOX M-26	Canada
Hi-VAWT Technology Corp.	DS300	Taiwan
Primus Wind Power	Air 40, Air Breeze, Air 30, Air X Marine, Air Silent X, AirMax X	Colorado
Star Wind Turbines	STAR72	Vermont

Table A.2. Wind Turbines Greater than 100 kW in U.S. Distributed Wind Projects

Manufacturer	Model Names	Headquarters
GE Renewable Energy	2.3-116, 2.82-127	United States

Appendix B: Methodology

Pacific Northwest National Laboratory (PNNL) collects data for this annual market report through direct data requests and a review of other data sources. This appendix explains the PNNL team's data-collection methodology.

For small wind data, the PNNL team issued data requests to about 480 distributed wind manufacturers and suppliers, developers, installers, operations and maintenance (O&M) providers, state and federal agencies, utilities, and trade associations. The team compiled responses and information from these data requests (with all sources listed in the Acknowledgments section) to tabulate the deployed United States and exported small wind capacity and associated statistics as of the end of 2022. The detail with which the different respondents answered the data requests varied, thus the team includes sample sizes and qualifications with certain analysis presentations as needed.

For distributed wind projects using turbines greater than 100 kW, the PNNL team issued data requests to project developers and reviewed other data sources to assess projects on a per-project basis to determine whether they meet this report's definition of distributed wind and therefore should be included in the distributed wind project dataset. The reviewed sources include the American Clean Power Association's CleanIQ database, the Federal Aviation Administration, the U.S. Wind Turbine Database, the U.S. Energy Information Administration, and the Federal Energy Regulatory Commission.

This report defines distributed wind as a distributed energy resource providing electricity for a specific on-site load or for a local load. This load can be served by a behind-the-meter, front-of-meter, or off-grid distributed wind project. Some front-of-meter projects may be connected to a distribution or transmission line for a distant customer, but because of their proximity to a city and the physics of electron flow, also provide distributed energy locally. These types of projects are considered "physically distributed" projects and are not counted in the capacity amounts presented in this report (Preziuso et al. 2022).

A project dataset was created to capture all known distributed wind projects installed in 2022. For projects using small wind turbines (up through 100 kW), project records were obtained directly from manufacturers and suppliers, O&M providers, utilities, and agencies through emails, phone interviews, or both. Project records collected for this report, and from past years, have been consolidated to produce a master project dataset available on PNNL's Distributed Wind Data website.

Projects reported for 2022 were cross-checked against previous records to avoid double counting. Small wind repower installations (in which either newly manufactured or refurbished turbines are installed on existing towers and foundations to replace nonfunctioning turbines or to upgrade the technology) are counted as new capacity in the given year and the existing project record is updated accordingly, so the project is not double counted. Sales and installation reports from manufacturers, suppliers, 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. Some newly installed projects in 2022 may use turbines sold many years ago, or donated turbines. Small wind turbine sales with project-specific records were added to the project dataset; however, most of the small wind turbine units sold in 2022 were not tracked at the project level.

The PNNL team 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 report details capacity figures for the same calendar year as the sales reported by the manufacturers and suppliers to tally annual deployed capacity. Most manufacturers report precise turbine units sold, but at least one manufacturer provides estimated turbine units sold because the company's less-than-1-kW size turbine units are shipped in bulk to distributors for resale to end users. Some installations occur after the calendar year that the wind turbine units were sold, so sales and projects are recorded separately. A U.S. sales presence is defined as manufacturers and suppliers documenting at least one sale in the United States in 2022.

Because many small wind turbine units sold are not tracked at the project level, such as off-grid turbine units, the PNNL team is unable to include them in the master project dataset. Consequently, each year's reported annual deployed capacity is a combination of the small wind sales and the projects installed using turbines greater than 100 kW for the given year.

When the PNNL team identifies projects that were installed in past years but were not previously recorded, the team adds those projects to the master project dataset. Further, the PNNL team marks turbines confirmed to be decommissioned in the dataset as such, but does not actively track decommissioning. The cumulative figures therefore principally represent annual capacity additions, rather than confirmed operating installations. Consequently, the cumulative capacity amount presented in this report represents deployed capacity, and capacity allocations by state and by year, may differ slightly from report to report.

The master project dataset is used to make year-to-year comparisons; allocate capacity amounts across states; analyze installed costs; identify incentive funding levels; and characterize distributed wind customers, types of turbines and towers, and project applications.

Incentive payments and reports can lag or precede sales reports or project installations. This report tallies and reports incentive payments for the year in which they were granted or paid, 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.

The PNNL team documents installed costs primarily from installers, developers, agencies, public sources such as press releases and news articles, and a few private sources. For projects using turbines greater than 100 kW, the PNNL team and the Lawrence Berkeley National Laboratory team, which authors the annual Land-Based Wind Market Report, share and cross-reference installed cost data for distributed wind projects. In some instances, installed cost figures are estimated based on reported incentive values. The PNNL team developed the reported investment values for 2022 using reported installed cost data and in-house estimates based on past projects and PNNL's Benchmarking U.S. Small Wind Costs report when needed (Orrell and Poehlman 2017). The reported O&M costs are also based on data collected for Orrell and Poehlman (2017) and from data requests from previous years.

Requests for international small wind capacity reports are issued annually to international contacts to obtain the most up-to-date small wind installation numbers with a country-by-country approach. Due to variability in responses, data are presented inconsistently year to year and from country to country. The level of accuracy included in responses is also variable, with some countries providing detailed numbers and others providing estimates. PNNL obtained additional international data and information from members of the International Energy Agency Wind Technical Collaboration Programme Task 41 and from presentations during a World Wind Energy Association webinar.

Levelized cost of energy (LCOE) calculations in future reports will use the following formula:[32]

$$LCOE = \frac{(FCR \times ICC) + O\&M}{AEPnet}$$

where

FCR	=	fixed charge rate = (0.074), assuming a 20-year loan at 4.0% interest
ICC	=	installed capital cost ($)
O&M	=	annual O&M cost ($)
AEPnet	=	net annual energy production (kWh/yr)

[32] The National Renewable Energy Laboratory's LCOE formula includes a levelized replacement cost that has been excluded here.

Table B.1 presents the rated or referenced small wind capacities used in capacity factor, LCOE, maintenance cost per kW, and installed cost-per-kW calculations.

Table B.1. Turbine Models in Small Wind Dataset

Turbine Model	Rated or Referenced Power at 11 m/s (kW)	Nominal Turbine Capacity (kW)	Rated or Referenced Power Source
Bergey Excel 6	5.5	6	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009 (Certification Expired)
Bergey Excel 10	8.9	10	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009
Bergey Excel 15	15.6	15	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009
Dakota Turbines DT-25	23.9	25	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009 (Certification Expired)
Endurance E-3120	56	50	ICC–SWCC power performance certification to IEC 61400-12-1 (Certification Expired)
Endurance S-343	5.4	5	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009 (Certification Expired)
Eocycle EO25 (now EOX S-16)	28.9	25	SGS Certification to AWEA 9.1–2009
Gaia GW 133-11	10.7	11	United Kingdom Microgeneration Certification Scheme certification to IEC 61400-12-1 as of January 2015
NPS 100-21	79	100	DNV power performance certification to IEC 61400-12-1
NPS 100-24	90	100	Manufacturer's power curve
Osiris 10	9.8	10	Intertek full certification to AWEA 9.1-2009 (Certification Expired)
Pika T701	1.5	1.7	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009 (Certification Expired)
Southwest Windpower/ Xzeres Skystream 3.7	2.1	2.4	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009 (Certification Expired)
Sonkyo Energy Windspot 3.5	3.5	3.2	Intertek full certification to AWEA 9.1-2009 (Certification Expired)
Xzeres 442SR	10.4	10	ICC–SWCC Small Wind Turbine Certification to AWEA 9.1–2009 (Certification Expired)

Distributed Wind Market Report: 2023 Edition

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Cover details: This is one of two 2.82-megawatt GE wind turbines powering a Dole Fresh Vegetables facility in Soledad, California. Photo from Foundation Windpower, LLC.