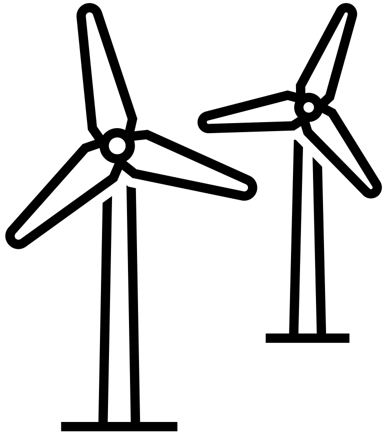
NREL
Transforming ENERGY



Technology Tips for REAP Application Reviews: Distributed Wind Energy

U.S. Department of Agriculture (USDA)
National Renewable Energy Laboratory (NREL)
Edward Baring-Gould

June 18, 2024

NREL/PR-5000-90382

Agenda

1. Welcome (5 mins) - Tonya Mosley, USDA
2. Distributed Wind 101 (20 mins) - Ian Baring-Gould, NREL
3. Distributed Wind Applications for REAP (20 mins) - Fred Petok, USDA
4. Q&A (15 mins) - USDA/NREL

Upcoming USDA/NREL Events

USDA REAP Funding for Your Solar + Storage Project (for applicants)
July 17, 2024, 1-2:30 MST

Technology Tips for REAP Application Reviews: Solar (for internal staff)
August 22, 2024, 10 a.m. - 11 a.m. MST

Technology Tips for REAP Application Reviews: Geothermal (for internal staff)
September 11, 11 a.m. - 12 p.m. MST

USDA REAP Funding for Your Geothermal Energy Project (for applicants)
September 16, 11 a.m. - 12:30 p.m. MST

What is Distributed Wind?

Method Soap Manufacturing Facility


Photo from Patsy McEnroe Photography

The Method Soap facility was built on a former brownfield.

What	One refurbished 600-kW NEG Micon NM48 wind turbine
When	2015
Where	Chicago, Illinois
How	Installed by a local developer
Why	To become an eco-friendly facility

Heritage Dairy Farm


Photo from Charles Newcomb

The two NPS wind turbines each produce nearly 240,000 kWh per year.

What	Two 100-kW Northern Power System (NPS) wind turbines
When	2016
Where	Yuma, Colorado
How	Installed by a local developer
Why	To offset electricity usage (50-60% electricity offset)

Champion Valley Feed Yard

Photo from Eocycle

The wind turbine reduces the feed yard's greenhouse gas footprint by producing over 90,000 kWh of clean energy per year.

What	One 25-kW Eocycle wind turbine
When	2019
Where	Yuma, Colorado
How	Designed and installed by Eocycle
Why	To reduce electricity cost and increase sustainability

Minnick Grain Farm

Photo from Eocycle

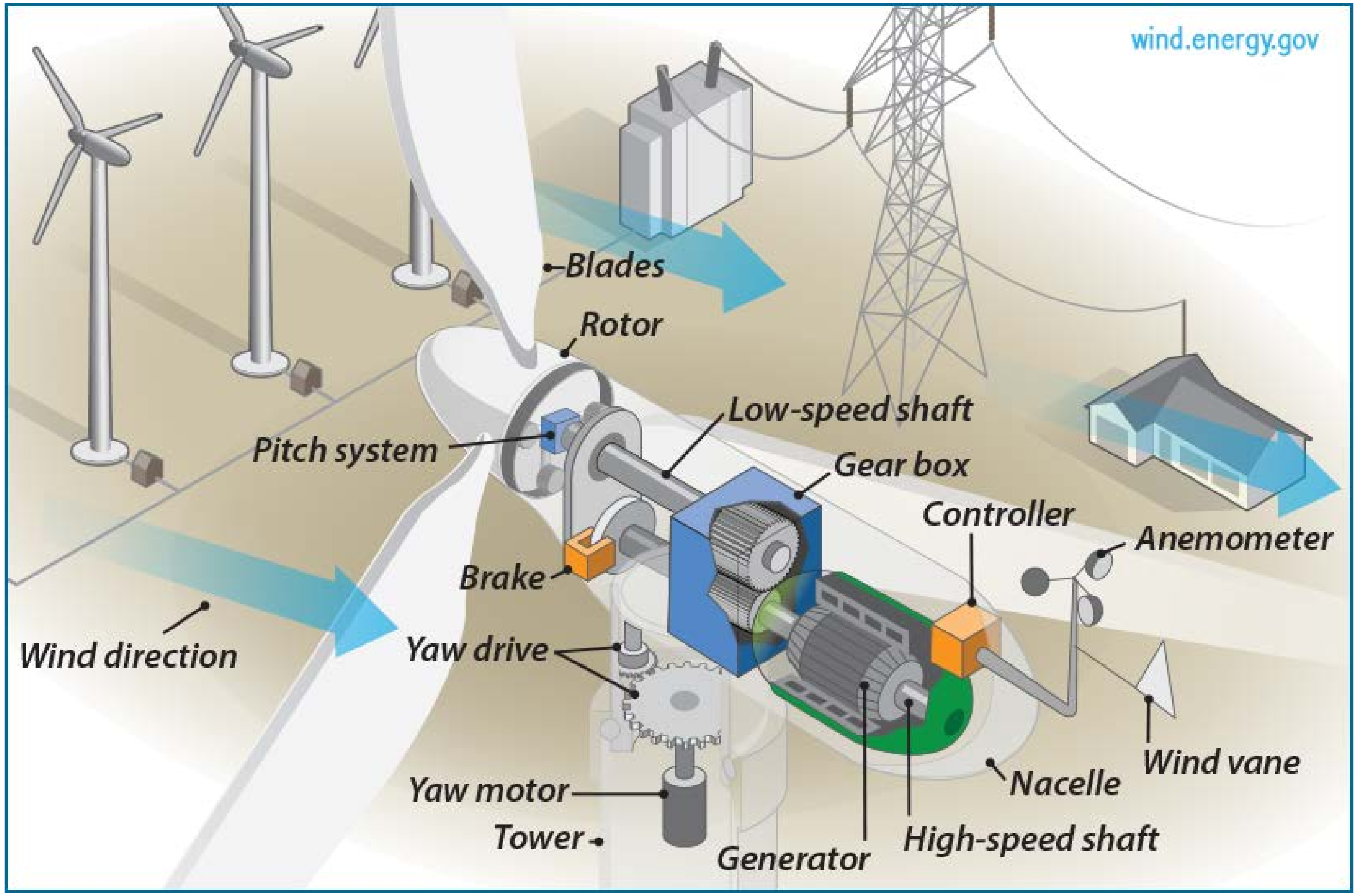
After leasing some of his land for large wind farms, this farmer decided he wanted a wind turbine of his own.

What	One 25-kW Eocycle wind turbine
When	2020
Where	Cosmos, Minnesota
How	Designed and installed by Eocycle
Why	To save on electricity bill (30-50% bill savings)

Wind Turbine Technology – The Basics

Wind Turbine Technology Basics

Many different designs are available, but all use aerodynamic lift on the blades or drag on a capture device, causing them to rotate, turning a generator where potential energy is converted into electricity.



Wind Turbine Power Basics

- Wind speed is critical for wind power production
  - Power generation is based on wind speed cubed
    - If wind speed doubles, power output increases by a factor of eight
  - Wind speeds increase with higher elevations
  - While higher wind speeds mean more power production, gusts of high-speed wind are not ideal
    - A steady, consistent wind resource is ideal

Wind Turbine Power (P) = ½ * ρ * A * V^3

- P = power (Watts)
- ρ = air density (kg/m^3)
- A = rotor swept area (m^2)
- V = wind speed (meters per second)

Wind speed is important!

However! All turbines can only extract 59.3% of the power available in wind - this is known as the *Betz Limit*

Wind Turbine Sizes

Distributed wind turbines can provide electricity for all types of customers

Photo from Bergey Windpower Co. Inc., NREL

Small (≤100 kW)

Homes

Farms

Remote applications (e.g., water pumping, telecom sites, ice making)

Photo from Tjaden Farms, NREL 13764

Mid-scale (100–1,000 kW)

Village and hybrid power

Community and distributed power

Small commercial and industrial applications

Photo from Native Energy Inc., NREL 7593

Large, land-based (1–3 MW)

Large commercial and industrial deployments

Large distributed power

Utility-scale wind farms

Photo from HC Sorensen, NREL 17855

Large, offshore (3–7 MW)

Utility-scale wind farms, shallow coastal waters with transition to deep water

Types of Wind Turbine Technology

Horizontal Axis Wind Turbines (HAWTs)

- Axis of rotation is parallel to the wind stream
- The dominant configuration in the marketplace

Photo from Cliff Ryden

Photo from Anneliese Mari Fensch

Vertical Axis Wind Turbines (VAWTs)

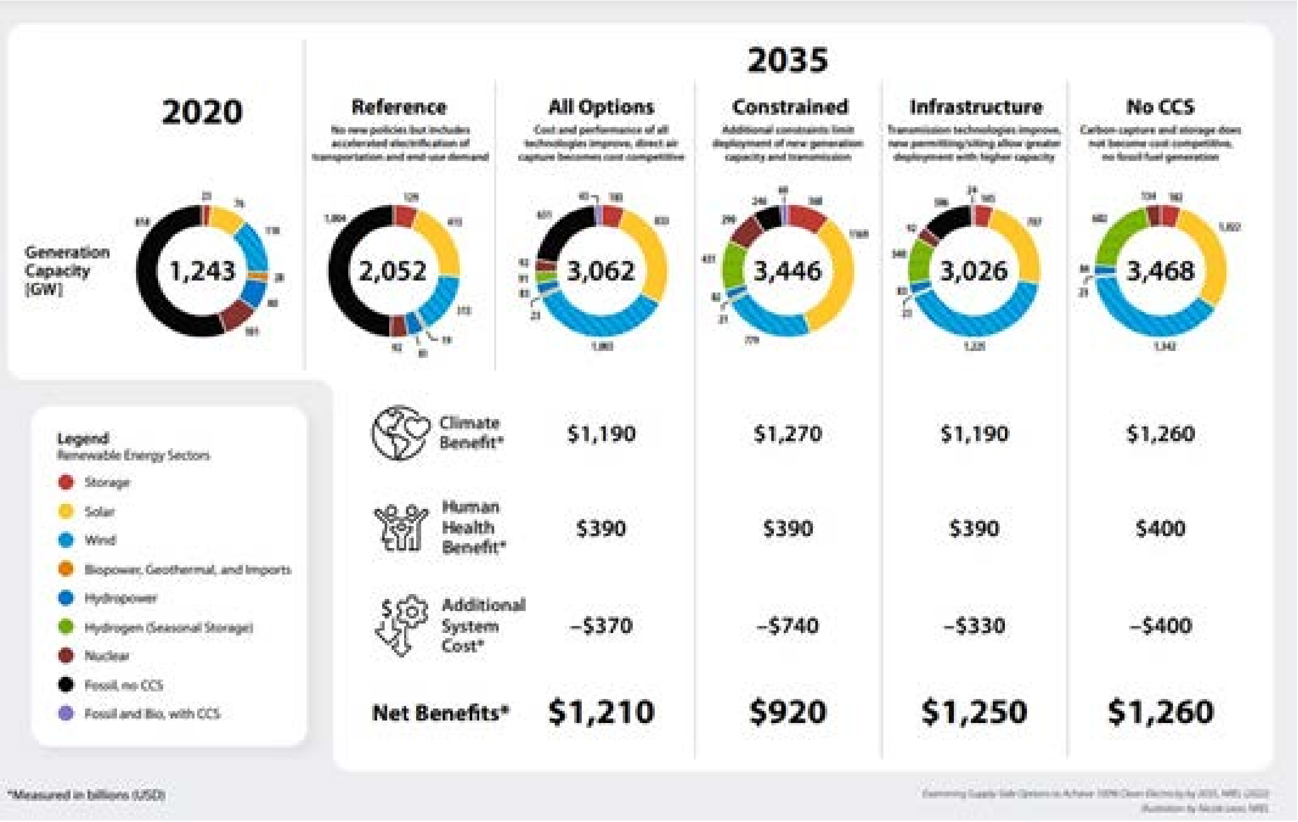
- Axis of rotation is perpendicular to ground
- More challenged in terms of efficiency, performance, and achieving certification to industry standards

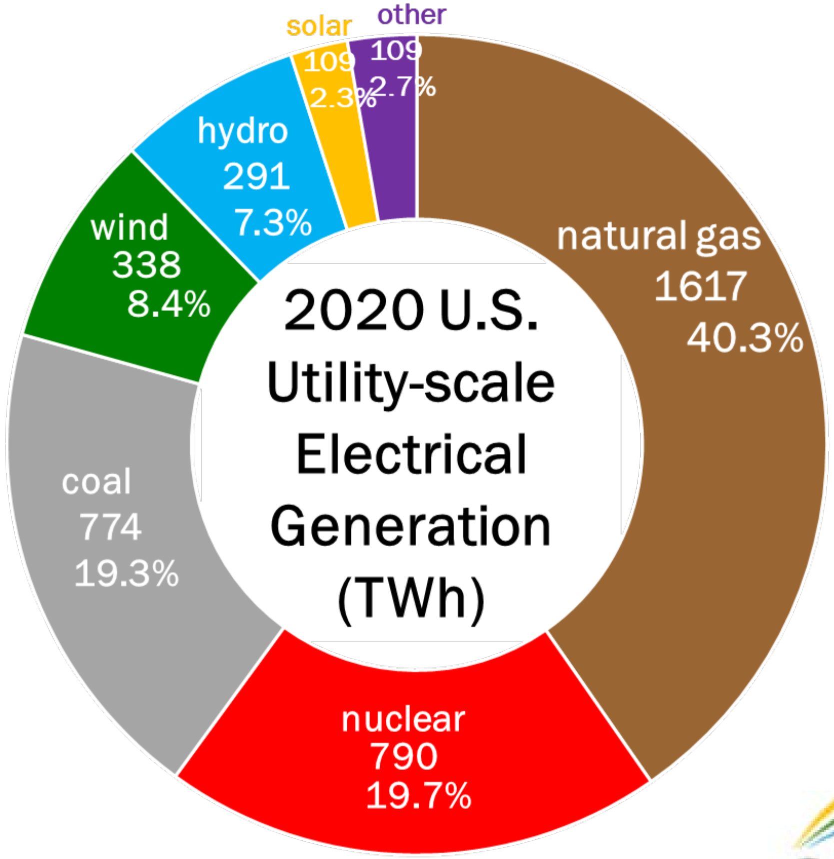
Photo from Wikipedia Commons

Photo from Guillaume Paumier

Transitioning to a Decarbonized Electricity System Provides Large Benefits to Consumers

There are many pathways to the decarbonization of the electricity grid based on renewable energy by 2035, but all call for very large deployments of wind and solar energy (Denholm 2022)



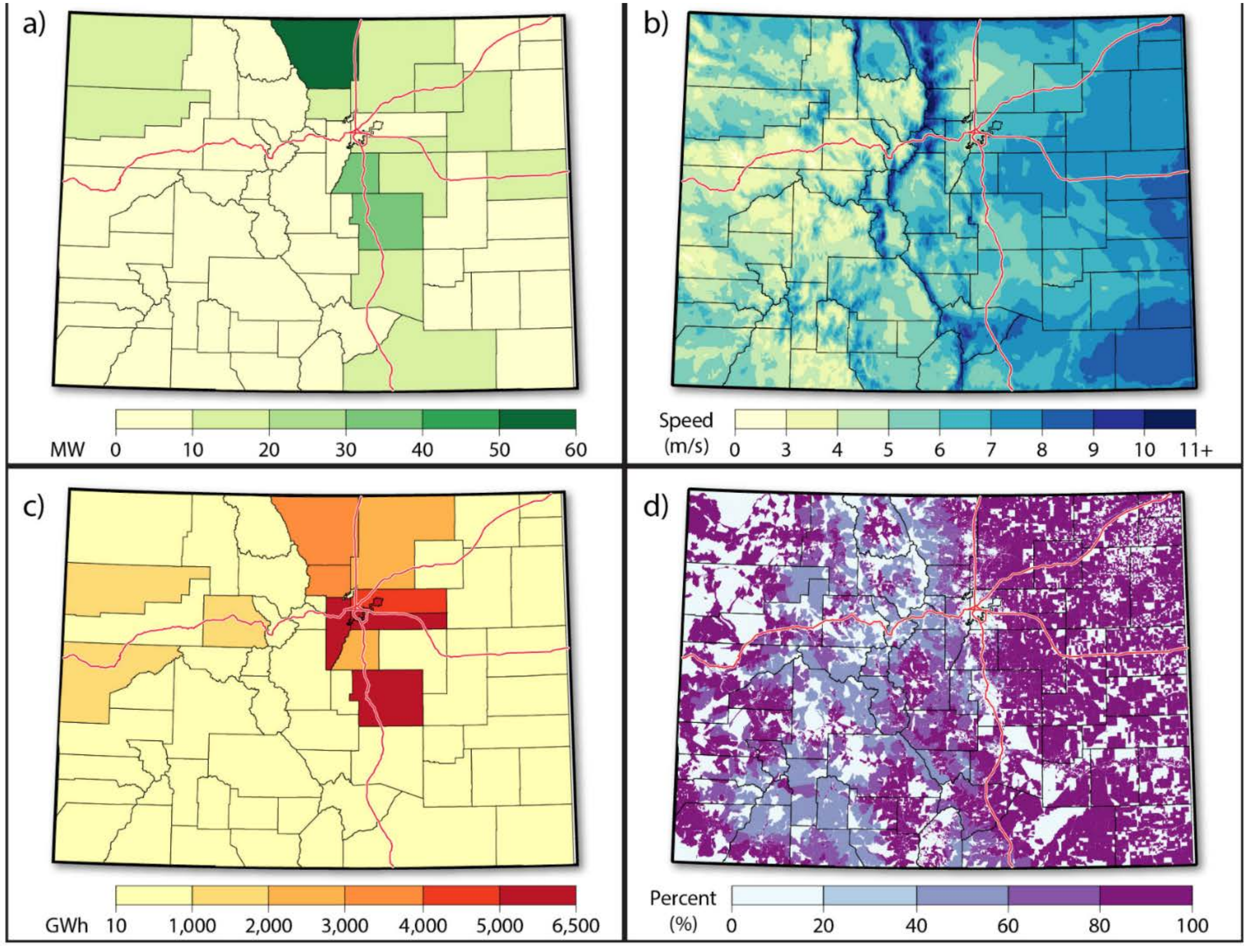


Electric Power Monthly

Distributed Wind 101

NREL-based modeling shows strong potential for wind development

Areas with good wind resource outside of developed areas show very strong potential for behind-the-meter development.

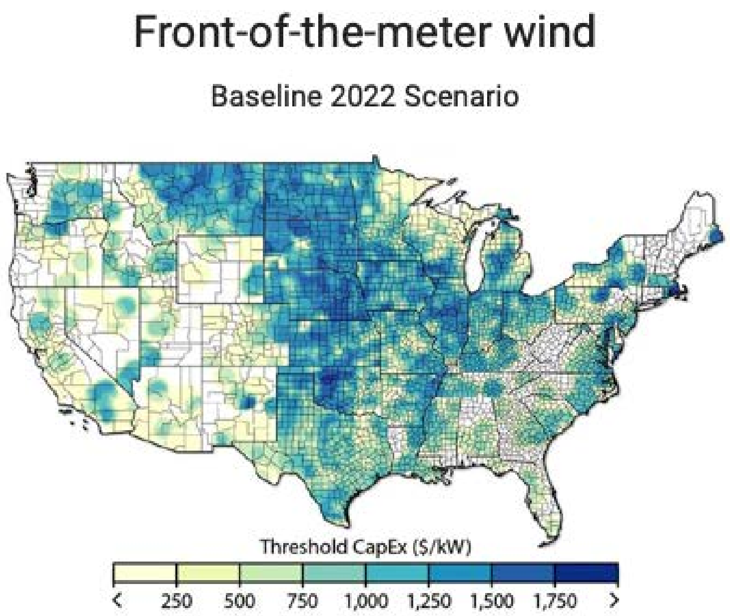


You don’t end up deploying in areas with the best wind resource! Potential behind-the-meter installations (upper left) are driven by wind resource (upper right), electricity costs (lower left), and lot size of potential users (lower right).

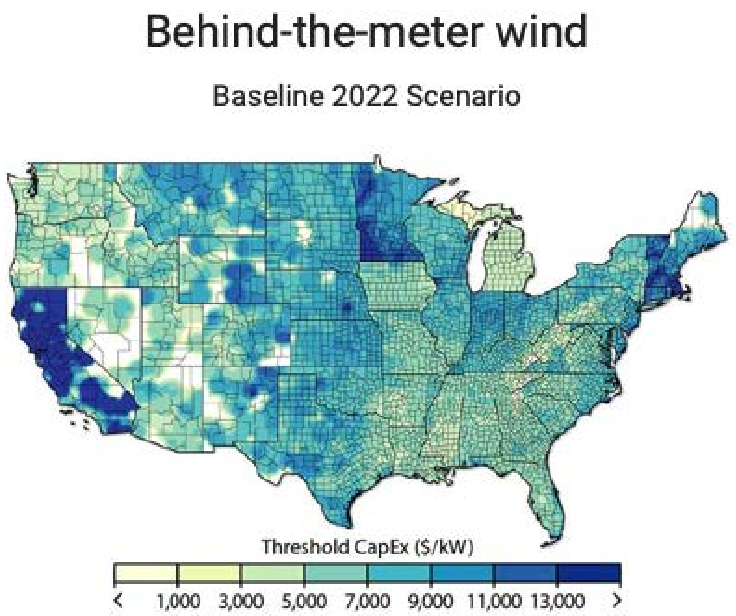
McCabe, Kevin, et al. 2018. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-70547. https://www.nrel.gov/docs/fy18osti/70547.pdf.

How much distributed wind development is viable?

The United States currently has the potential to profitably deploy hundreds of gigawatts (GW) of distributed wind energy capacity



The economic potential of front-of-the-meter wind applications in 2022. Oklahoma, Nebraska, Illinois, Kansas, Iowa, South Dakota, Pennsylvania, New York, Montana, and New Mexico have the highest potential.



The economic potential of behind-the-meter wind applications in 2022. Texas, Minnesota, Montana, Colorado, Oklahoma, Indiana, South Dakota, North Dakota, New Mexico, and Kentucky have the greatest economic potential.

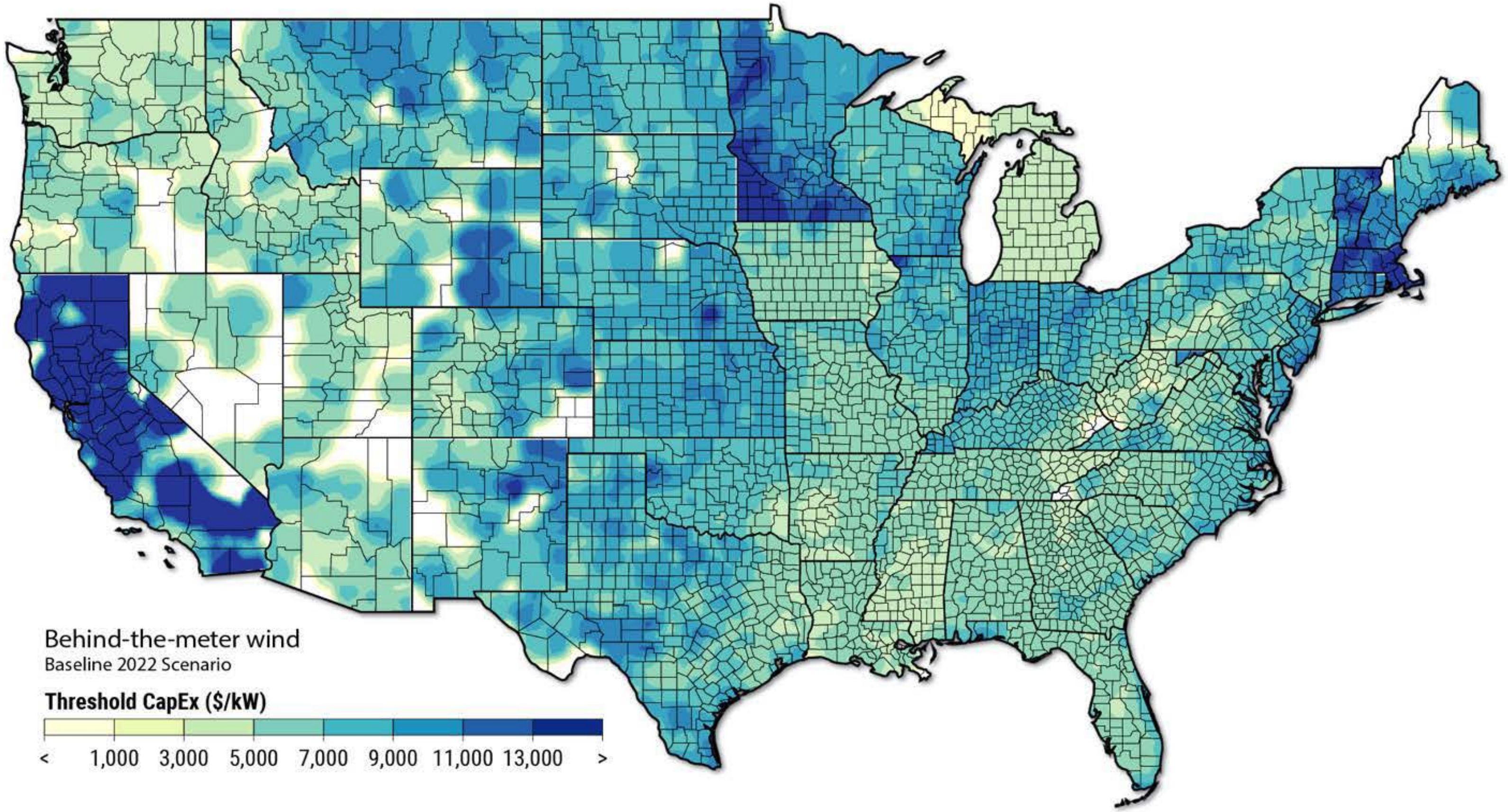
This amount equates to more than half of the nation's current annual electricity consumption

Economic Potential for Behind-the-Meter Installations

In the NREL Distributed Wind Energy Futures Study, a metric of economic potential is Threshold Capital Expenditure (Threshold CapEx).

Threshold CapEx ($/kW) is the highest cost at which a project can be installed and still achieve a positive rate of return. **The higher the threshold CapEx, the higher the favorability for distributed wind energy**.

In the U.S. heat map of results on the right, the darker the color, the higher the Threshold CapEx.



Behind-the-meter economic potential in terms of threshold CapEx for a baseline 2022 scenario

Source: https://www.nrel.gov/analysis/distributed-wind-futures.html

Three states led the United States in new distributed wind capacity: Iowa, California, Nebraska

In 2022, new distributed wind projects were documented in 13 states:

California	New York
Iowa	Ohio
Kansas	Illinois
Michigan	Virginia
Minnesota	Vermont
Montana	Wisconsin
Nebraska	

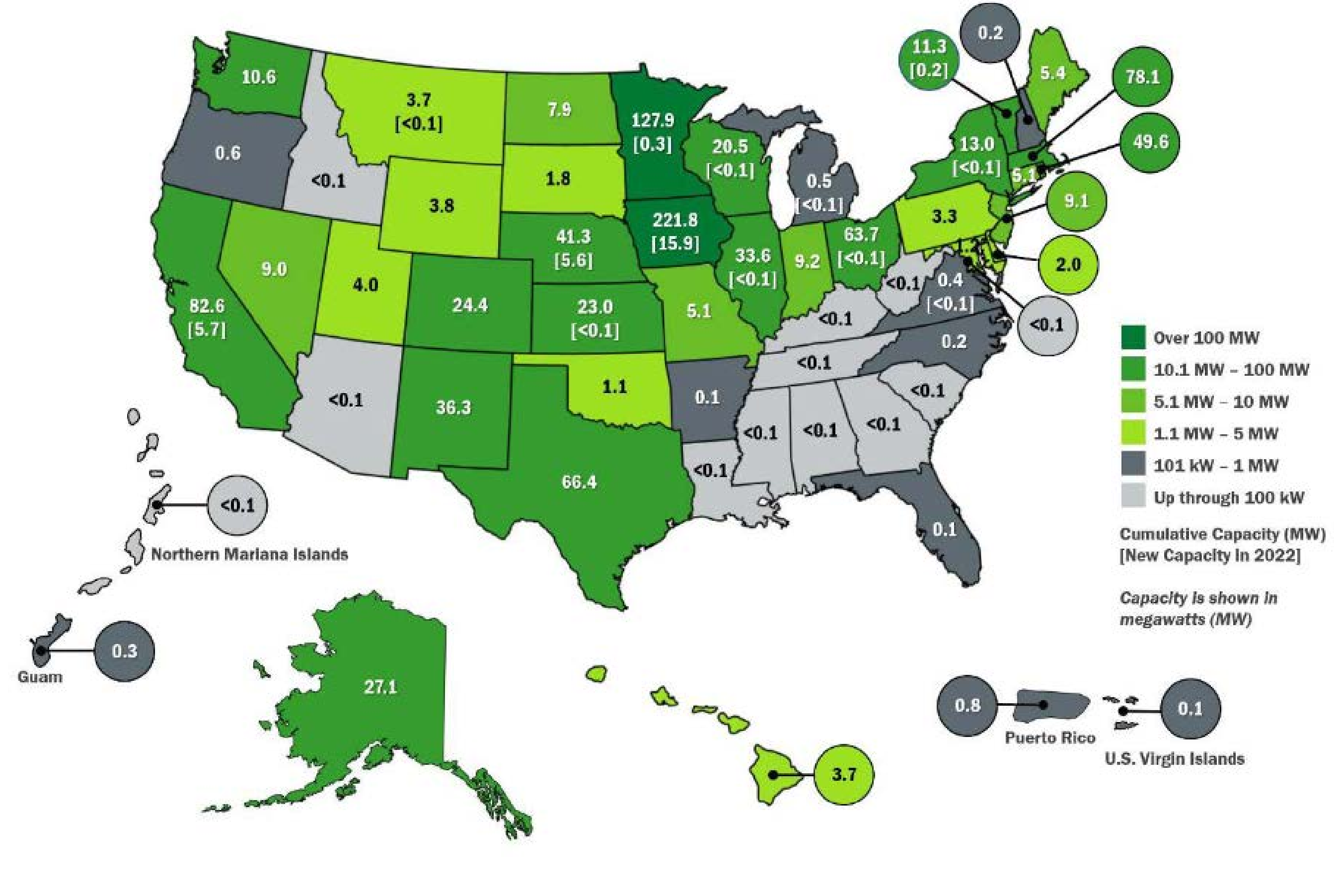


Figure 2. U.S. cumulative (2003–2022) capacity and capacity additions in 2022 for distributed wind by state

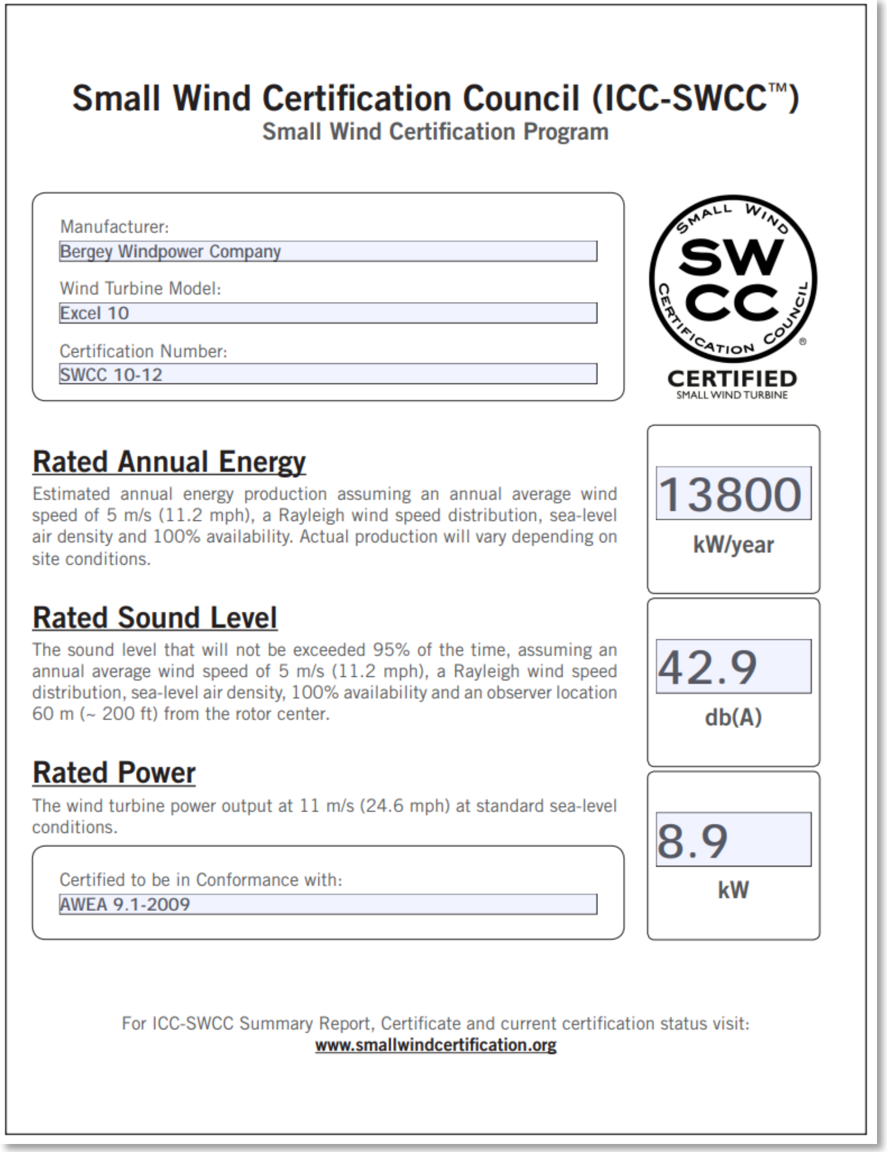
U.S. cumulative (2003–2022) capacity and 2022 capacity additions for distributed wind by state

Small Wind Turbine Certification

Turbine Certification

- What is Certification?
  - The formal process through which an independent organization performs conformity assessment of a turbine to established criteria in industry standards

- Why is it Important?
  - Provides consumer protection; helps prevent unethical marketing and false claims
  - Allows turbine manufacturers to demonstrate that the turbine model meets performance, durability, and quality standards
  - Allows for apples-to-apples comparisons for consumers
  - Funding agencies and utilities have greater confidence that wind turbines installed with public funds have been tested for safety, function, performance and durability
  - Some incentive programs may only fund certified turbines



Small Wind Certification Council (ICC-SWCC™)
Small Wind Certification Program

Manufacturer: Bergey Windpower Company
Wind Turbine Model: Excel 10
Certification Number: SWCC 10-12

SMALL WIND CERTIFICATION COUNCIL SW CC CERTIFIED SMALL WIND TURBINE

Rated Annual Energy — 13800 kW/year
Estimated annual energy production assuming an annual average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, sea-level air density and 100% availability. Actual production will vary depending on site conditions.

Rated Sound Level — 42.9 db(A)
The sound level that will not be exceeded 95% of the time, assuming an annual average wind speed of 5 m/s (11.2 mph), a Rayleigh wind speed distribution, sea-level air density, 100% availability and an observer location 60 m (~ 200 ft) from the rotor center.

Rated Power — 8.9 kW
The wind turbine power output at 11 m/s (24.6 mph) at standard sea-level conditions.

Certified to be in Conformance with: AWEA 9.1-2009

For ICC-SWCC Summary Report, Certificate and current certification status visit:
www.smallwindcertification.org

U.S. Framework for Small Wind Turbine Certification

Small Wind Standards

IEC | AWEA American Wind Energy Association | American Clean Power Standards

Test Facilities

RE Innovations | Windward Engineering | UL Solutions | Renewtest LLC | NREL Transforming ENERGY

Certification Bodies

ICC-SWCC Small Wind Certification Council | SGS | DEWI OCC | DNV

- Small wind turbine models are certified to standards at test facilities by third-party, independent certification bodies
- Industry standards are the following:
  - AWEA 9.1-2009 Small Wind Turbine Standard: For small wind turbines up to about 65 kW
  - ACP 101.1-2021 Small Wind Turbine Standard: For small wind turbines having a peak power of 150 kW or less; can replace AWEA 9.1-2009
  - IEC 61400 -1 (design), -2 (small wind turbines) -11 (sound), and -12 (power performance)

Siting Considerations

Land Use for Small-Scale Distributed Wind

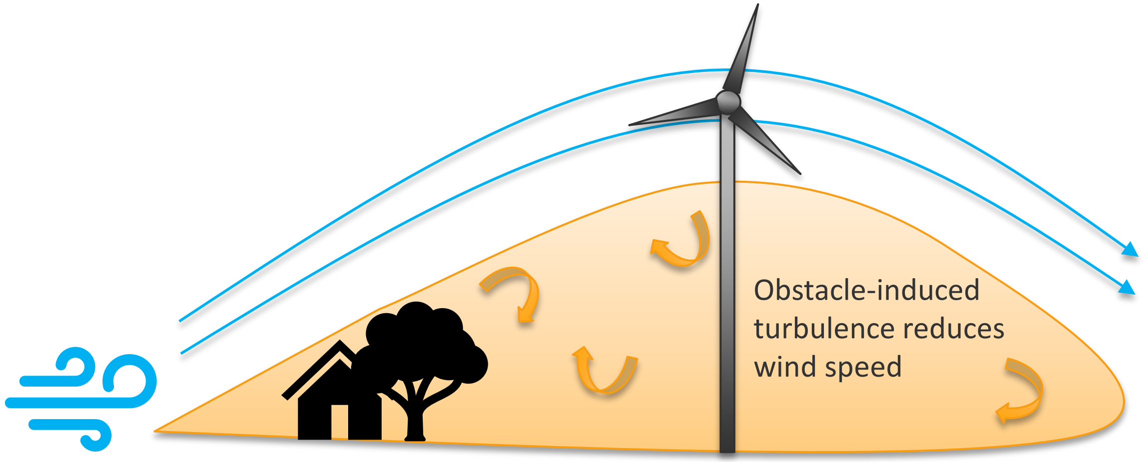
- Land use impacts may be non-existent or marginal for small wind
  - General rule of thumb for spacing: a minimum of 1 acre is typically required to allow for setbacks from neighbors and property lines and from obstacles that could cause turbulence
- Turbulence can be a major issue for small turbines because of their lower tower heights and location near homes and other buildings
  - Turbines need to be sited upwind of buildings and trees
  - A rule of thumb is for the tower to be 30 ft. above anything within a 500 ft. horizontal radius
  - For tilt-up towers, enough space is needed to raise and lower the tower for maintenance; for guyed towers, space is needed to secure the guy wires


Photo from Bruce Hatchett / Energy Options

Tower Height Considerations

How tall do distributed wind turbine towers need to be?

- Wind speed increases with height in the atmosphere
- Small increases in wind speed can result in large increases in wind power
- Tall towers are often needed to provide clearance above obstacles (buildings, trees)



Considerations:

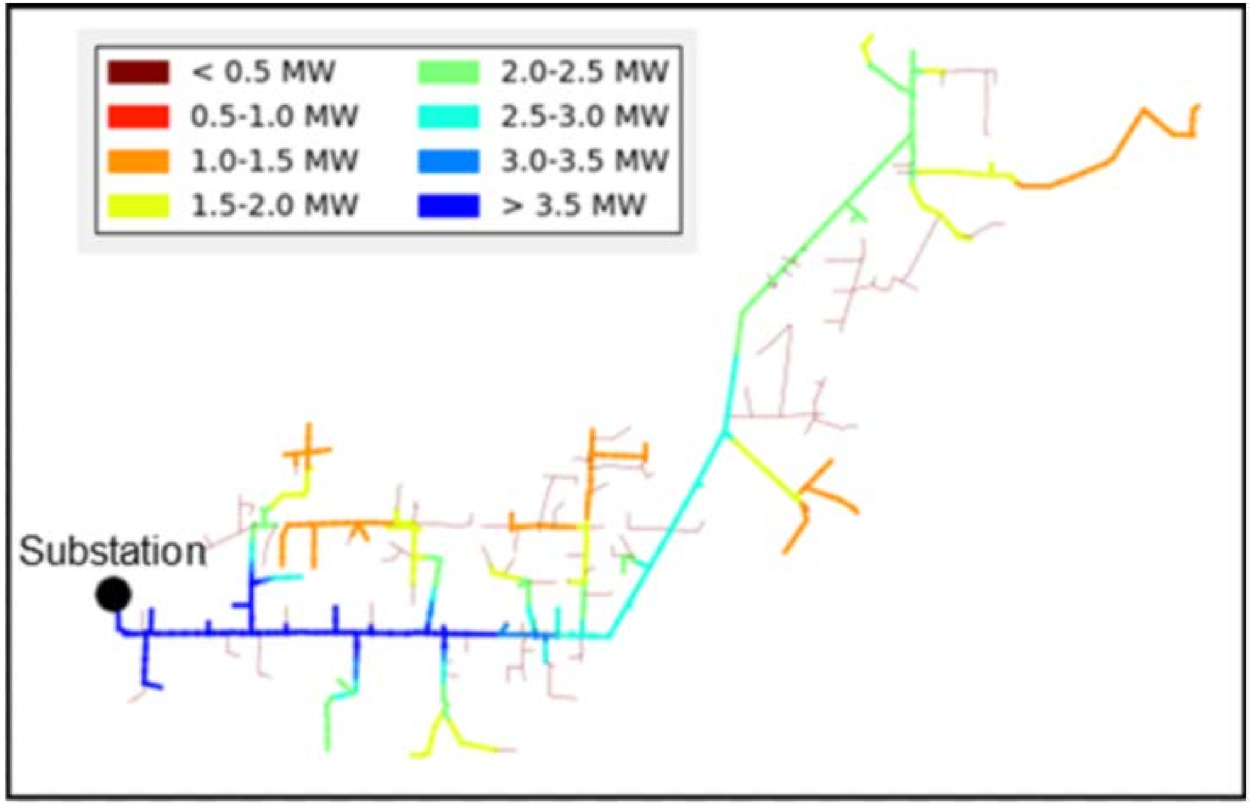
- Potential power production increases with the height of the wind turbine tower
- However, cost and permitting challenges also increase with the height of the wind turbine tower
- Depending on height and location, the Federal Aviation Administration may require the turbine to have nighttime lighting

Note: Tower heights are typically measured as the distance from the ground to the turbine rotor, which is also known as the "hub height"

Grid Interconnection

For grid connected energy systems:

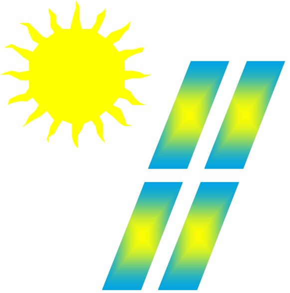
- State and local provider (power company) policies drive the conditions in which small-turbine consumers can connect distributed energy resources (DER) to the grid. Interconnection agreements typically cover
  - Disconnection requirements
  - Insurance and liability
  - Inspection and testing
  - Tariffs for billing & payment
- Need to work with local service providers to understand interconnection requirements, even for projects installed on the customer side of the utility meter
- Hosting capacity is the amount of DERs that can be added to a distribution feeder or circuit without affecting power quality or reliability.
- To safely and reliably integrate additional DERs beyond the hosting capacity limit, control or system upgrades would be required.

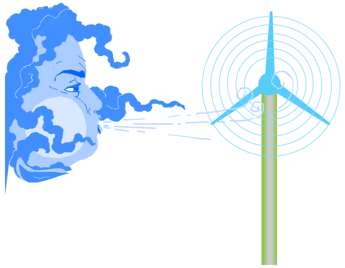


Example hosting capacity heat map which shows how the amount of potential generation reduces the farther you get away from the substation and main feeder line

Behind-the-Meter Energy Use

Energy consumed immediately





Excess energy used to ***offset*** consumption at another time over an allowed period, typically monthly or annually

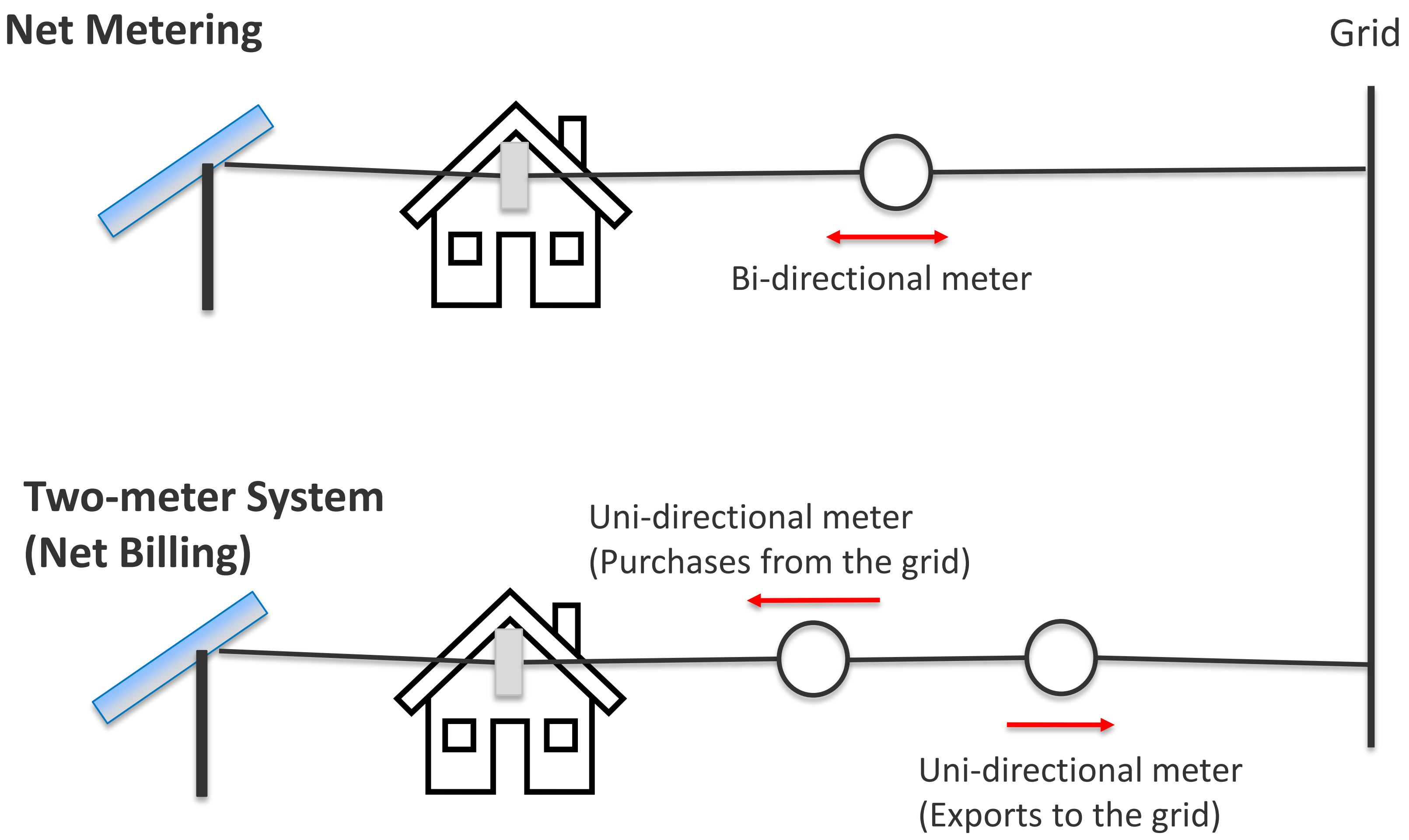
Net excess energy that can not be used by the consumer, banked or given to the utility

NREL: 57714

Net-Metering - What is it?

Net Metering: Offset energy is valued at the retail rate over a period – maximizing the value of renewable energy without concern for the time of day or season

Net Billing: Power exported to the grid has a different value – requiring more concern for when power is generated and consumed

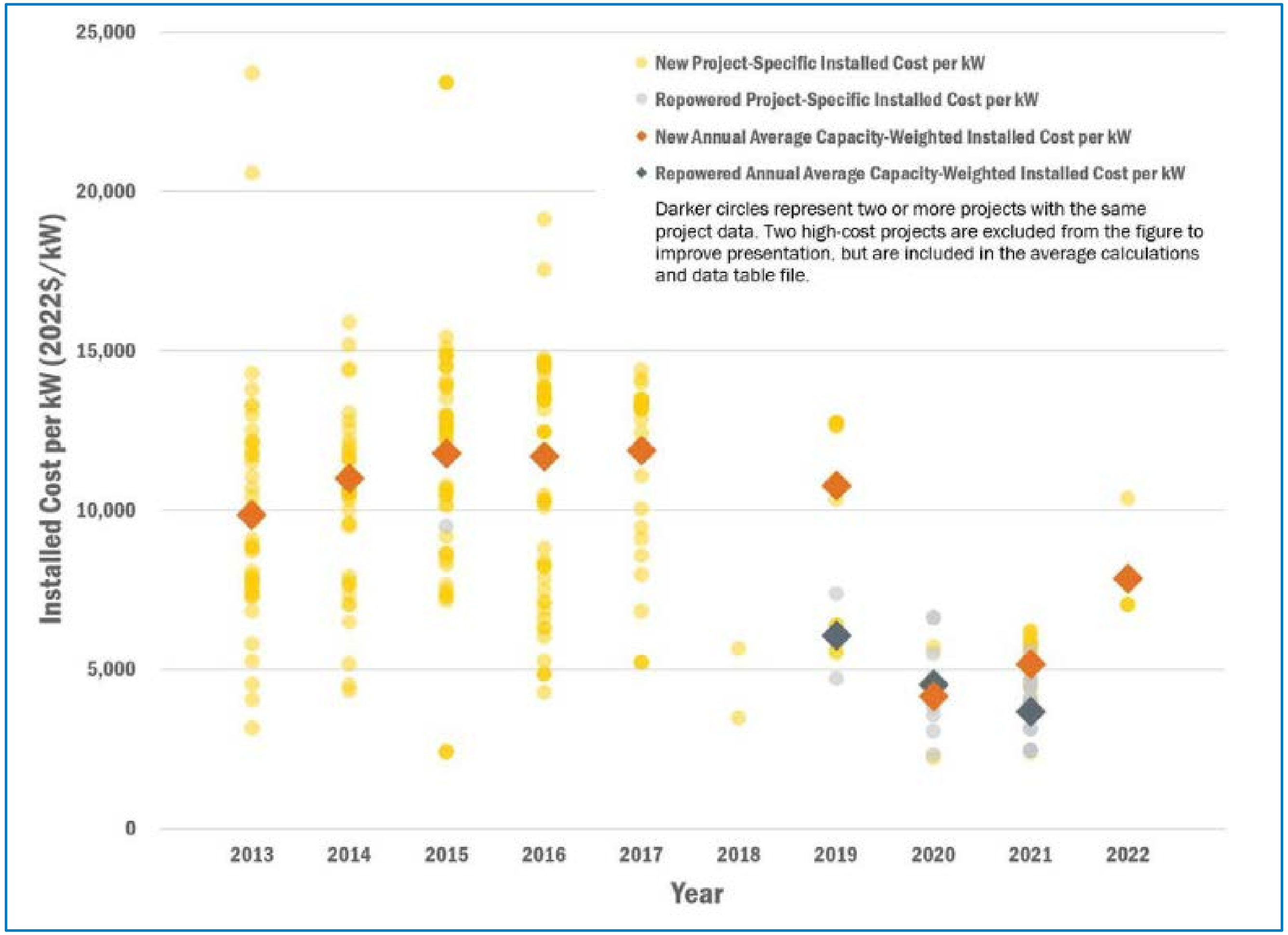


Additional Considerations

- Radar Interference
- Wind and Wildlife Impacts
- Reported Health Impacts
- Sound Emissions
- Shadow Flicker
- Ice fall / Ice throw, safety considerations
- Decommissioning

Costs

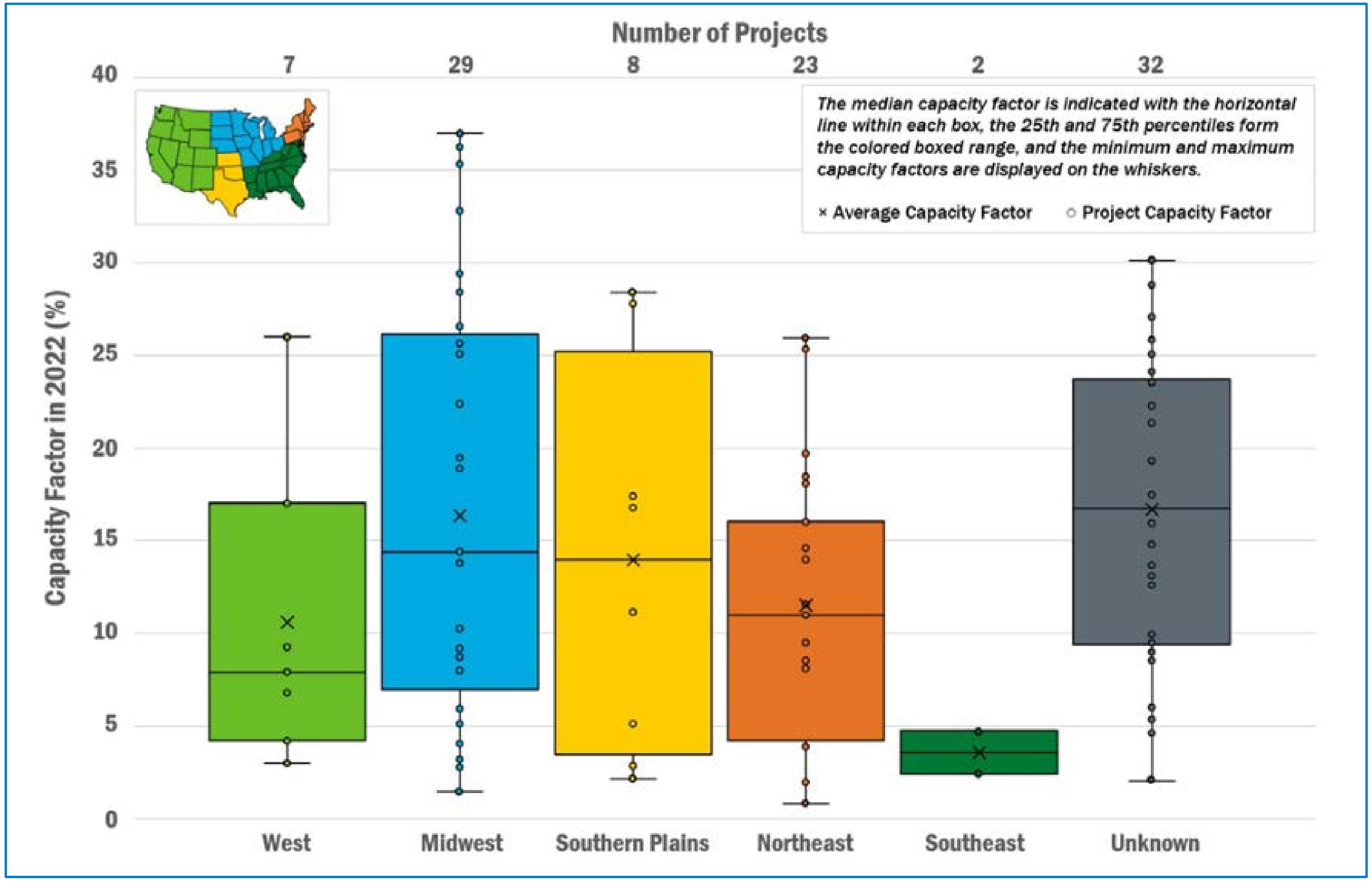
The average capacity-weighted installed cost for new small wind projects in 2022 was $7,850/kW.



Average and project-specific U.S. new and repowered small wind installed project costs, 2013–2022

The small wind average capacity factor from a sample of projects that generated energy in 2022 was 15%.

Locations with a capacity factor of less than 15% should be avoided.



Small wind capacity factors in 2022

Distributed Wind Applications for REAP

Rural Business Cooperative Service Wind Technology Review Tips

USDA Rural Development
U.S. DEPARTMENT OF AGRICULTURE

Look at the manufacture of the turbine and look up their references

SWCC labels, certificates and summary reports are accessible below for fully certified turbines.

Applicant	Turbine	Rated Annual Energy @ 5 m/s[1]	Rated Sound Level[2]	Rated Power @ 11 m/s[3]	Certification Granted[4]	Certification Number (Click for more info)
Bergey Windpower Co.	Excel 10	13,800 kWh	42.9 dB(A)	8.9 kW	11/16/2011	SWCC-10-12
Southwest Windpower	Skystream 3.7	3,420 kWh	41.2 dB(A)	2.1 kW	12/19/2011	SWCC-10-20

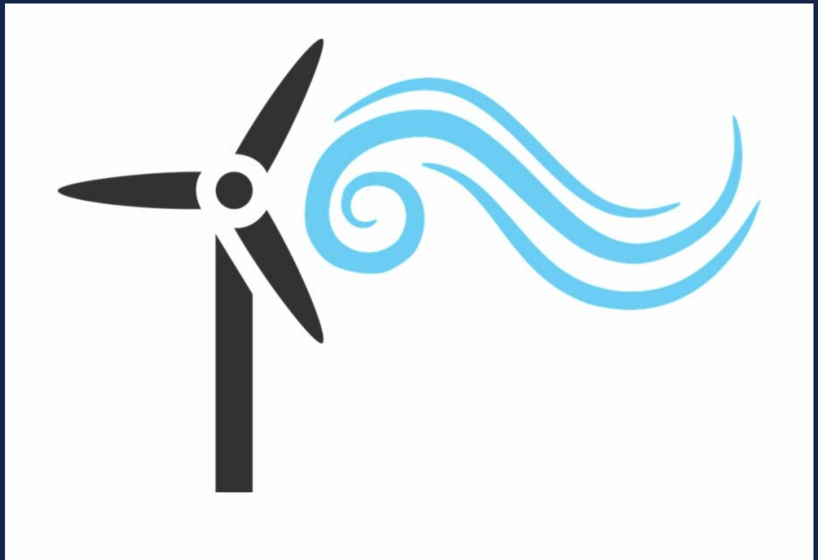
[1] Rated Annual Energy is the calculated total energy that would be produced during a one-year period with an average wind speed of 5 m/s (11.2 mph)

[2] Rated Sound Level is the sound pressure level (dBA) not exceeded by the wind turbine 95% of time at a distance of 60 meters from rotor with a hub height annual average wind speed of 5 m/s (11.2 mph)

[3] AWEA Rated Power is the wind turbineâ€™s power output at 11 m/s (24.6 mph)

Are the projected power numbers realistic?

Does this project make sense?



Is the power for the project's consumption or is it for sale? If for sale is there a power purchase agreement (PPA) or is net metered? Net metering agreements can change - they may not run for the term needed to have the project paid off.

Who is performing the work? Are they qualified? Have you verified the contractor’s qualifications and references?

If the project is supplied power to the facility site, how will it be wired to the current distribution system? Is the turbine going to supply AC power? What is the onsite power to be used?

Who is going to perform routine maintenance on the turbine? Where on the property will the turbine be sited? How was the site selected?

Wind. Provide adequate and appropriate data to demonstrate the amount of renewable resource available. Indicate the source of the wind data and the conditions of the wind monitoring when collected at the site or assumptions made when applying nearby wind data to the site.

For RES Projects, enable the calculation of the percentage of historical use of energy compared to the amount of renewable energy that will be generated once the project is operating at its steady state operating level. If the project is closely associated with a residence, demonstration must be made that 50 percent or more of the projected renewable energy will benefit the agricultural operation or rural small business; and

(iv) Demonstrate that the RES or EEI will operate or perform over the project's useful life in a reliable, safe, and a cost-effective manner, which may include but is not limited to addressing project design, installation, operation, maintenance, and warranties.

Relevant Resources and Q&A

General Resources

WINDExchange
U.S. DEPARTMENT OF ENERGY

- General information: WINDExchange Distributed Wind overview and Distributed Wind Energy Resource Hub
- Searchable wind resource time series: Wind resource data viewer
- Searchable monthly wind speed and production: Tools Assessing Performance
- Information on distributed wind developers and manufacturers: Distributed Wind Energy Association

Q&A

Wind Energy Basics

Resource	Description
WINDExchange	Platform that shares wind energy information with communities to make wind development decisions; understand siting, permitting, and installation processes; and weigh costs and benefits.
What is Distributed Wind?	Highlights the various research, development, and deployment programs being run by DOE’s Wind Energy Technologies Office.
How Distributed Wind Works	Explains how distributed wind works.
Distributed Wind Basics	Offers information on distributed wind (community wind and residential wind) and additional inputs on market condition and data.
Top Ten Things on Distributed Wind	Provides key points and fun facts about the U.S. distributed wind market.
Utility-Scale Wind Basics	Offers relevant information on utility-scale land-based wind.
Small Community Wind Handbook	Offers guidance for the siting and development activities required to develop a wind project in a small community.
Large Community Wind Handbook	Provides guidance for the siting and development activities required to develop a wind project in a large community.

Wind Energy Basics

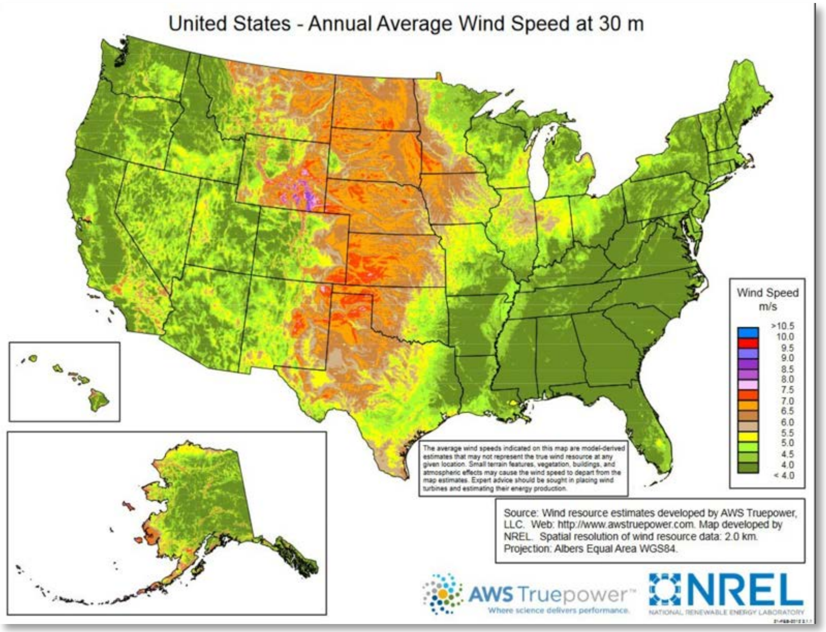
Resource	Description
Zoning and Permitting for Wind	Serves as a resource to facilitate the installation of distributed wind energy systems.
Distributed Wind Installers	Lists distributed wind installers for consumers' reference but does not represent an endorsement of any installer.
Selecting, Implementing, and Funding Distributed Wind Systems in Federal Facilities	Provides a free, on-demand training divided into modules. Only the financing module is hyper-specific to federal agencies.
Distributed Wind for Federal Agencies	Provides a free, on-demand training that reviews wind resource assessment screening tools and other distributed wind tools and resources.
RADWIND	Offers guidance from the Rural Area Distributed Wind Integration Network Development (RADWIND), which was a WETO-funded project led by the National Rural Electric Cooperative Association to address barriers to the adoption of distributed wind by rural utilities. Its resources include project development guidance.
RADWIND Case Studies	Shows case studies that highlight the experience of electric cooperatives and rural public power districts deploying or interconnecting distributed wind projects.
Distributed Wind Installers Collaborative Case Studies	Presents case studies that cover a variety of customers using distributed wind energy.
REPowering Schools	Provides programming and opportunities to engage and train a diverse and sustained renewable energy workforce.

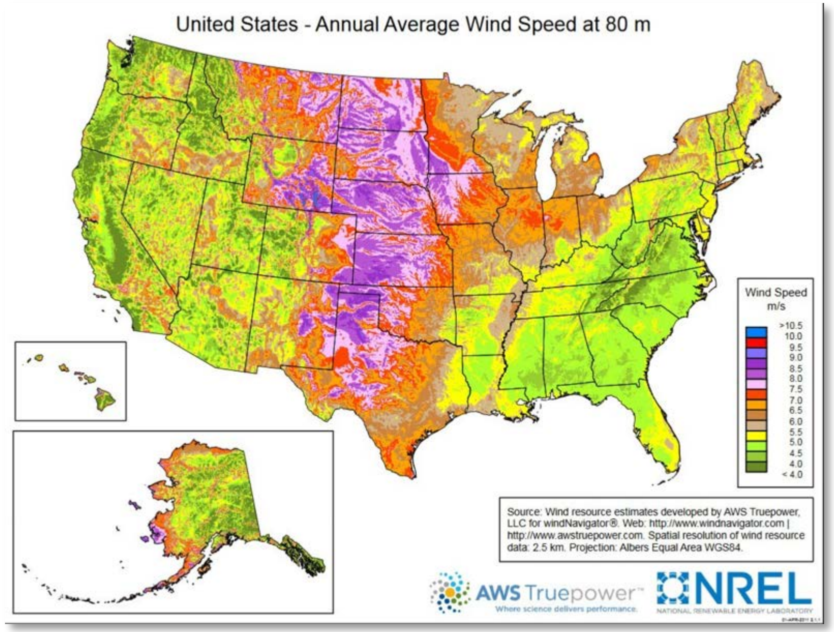
Data and Information

Resource	Description
Wind Technology Resource Center	Features technical resources from DOE on wind energy research topics through publications, data, and analysis.
The U.S. Wind Turbine Database	Offers a comprehensive dataset of U.S. wind turbine locations and characteristics that is updated quarterly.
Wind Energy Technologies Office Projects Maps	Details the Wind Energy Technologies Office's research and development portfolio.
Wind Energy Maps and Data	Shows existing wind capacity and the potential wind resources up to 140 meters above ground.
Wind Energy Technologies Office Publication and Product Library	Provides information about improving performance, lowering costs, and reducing market barriers for U.S. wind energy.
Distributed Wind Photo Gallery	Case studies to educate consumers on the many facets and opportunities within the distributed wind industry.
Distributed Wind Research—NREL	Outlines NREL's distributed and small wind research.
Distributed Wind Research—PNNL	Summarizes PNNL's distributed and small wind research.
Distributed Wind Database	Presents PNNL's distributed wind data from turbine manufacturers, operations and maintenance providers, state and federal agencies, and other stakeholders for projects installed in the United States.

Wind Resource Assessment

Resource	Description
[WINDExchange]()	Features wind energy resource assessment maps, data and trends.
[Wind resource data viewer]()	Identifies high-wind areas for wind power generation.
[DW-TAP API]()	Offers estimates of wind direction, wind speed, and wind power.





Financial Analysis

Resource	Description
Cost of Renewable Energy Spreadsheet Tool (CREST)	Contains economic, cash-flow models designed to assess project economics, design cost-based incentives, and evaluate the impact of state and federal support structures on renewable energy.
System Advisor Model (SAM)	Free techno-economic software model that facilitates decision-making for people in the renewable energy industry.
Levelized Cost of Energy (LCOE) Calculator	Provides a simple way to calculate a metric that encompasses capital costs, operations and maintenance (O&M), performance, and fuel costs of renewable energy technologies.
Renewable Energy Integration and Optimization (REopt)	Techno-economic decision support platform that helps optimize energy systems for buildings, campuses, communities, microgrids, and more.
Jobs and Economic Development Impact (JEDI)	Estimates the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels.
Annual Technology Baseline (ATB)	Features consistent, freely available, technology-specific cost and performance parameters across a range of research and development advancements scenarios, resource characteristics, sites, fuel prices, and financial assumptions for electricity-generating technologies, both at present and with projections through 2050.