NREL

Session 2: Siting, Zoning Ordinances, and Interconnection

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Clean Energy Resource Teams
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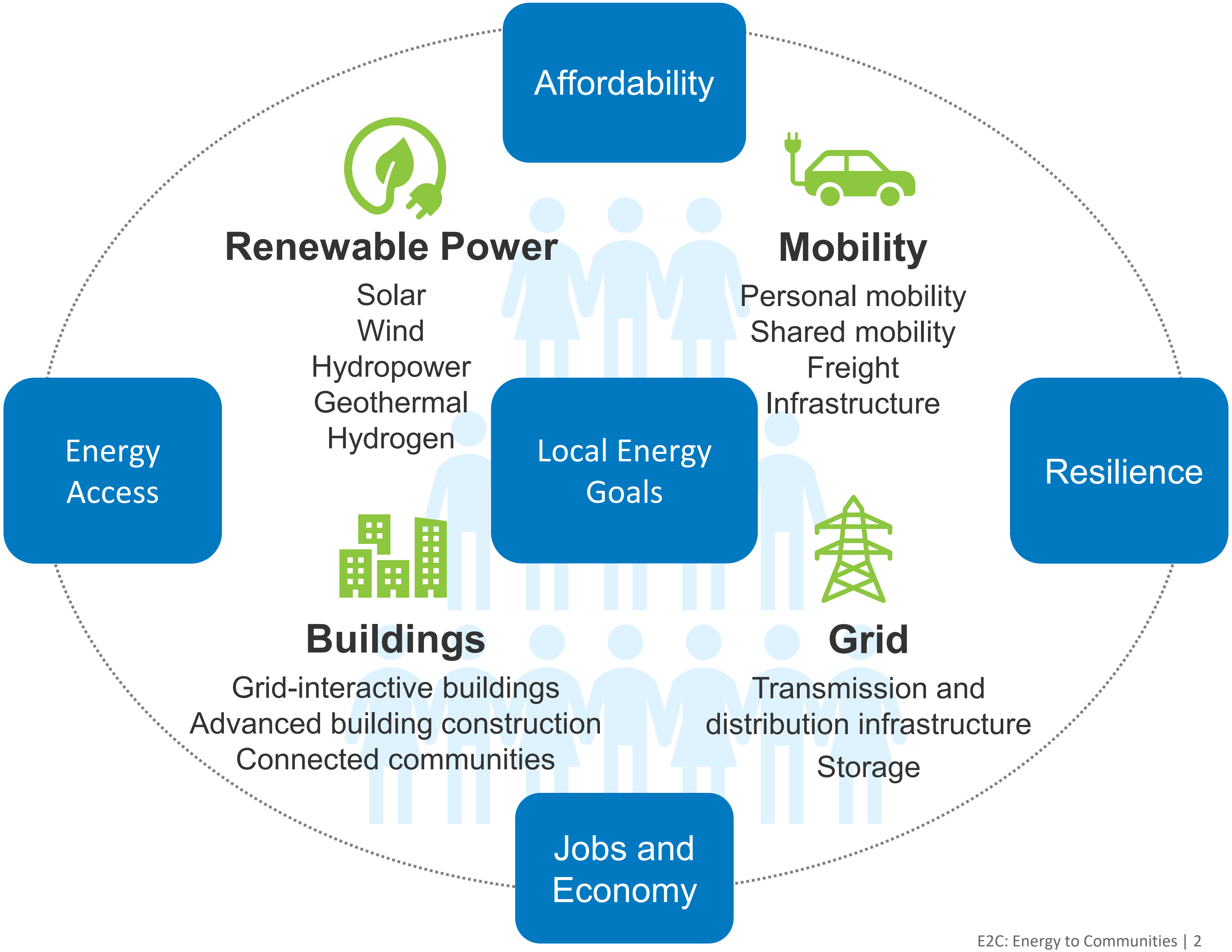
Photo by Gregory Cooper/NREL

E2C provides innovative, cross-cutting technical solutions using an integrated approach.



Energy to Communities (E2C)

Technical Assistance Opportunities

In-Depth Partnerships ~3 years

Multiyear partnership made up of teams (local governments, community-based organizations, and electric utilities) that work alongside national laboratory staff to apply robust modeling and analysis tools and conduct hardware-in-the-loop testing of solutions to evaluate potential scenarios and strategies before full technology deployment.

Supports nine communities currently.

Peer-Learning Cohorts ~6 months

Multi-community engagements that convene regularly for approximately 6 months to exchange strategies and best practices, learn in a collaborative environment, and workshop plans and strategies to overcome challenges around a common energy transition topic. Eligibility varies by cohort topic.

Supports about 100 communities per year.

Expert Match ~3 months

Short-term, no-cost technical assistance for communities seeking to answer near-term energy questions. Eligible entities include local governments, utilities, community-based organizations, schools, and nonprofits.

Supports about 200 communities per year. ***Applications are accepted all year on a rolling basis.***

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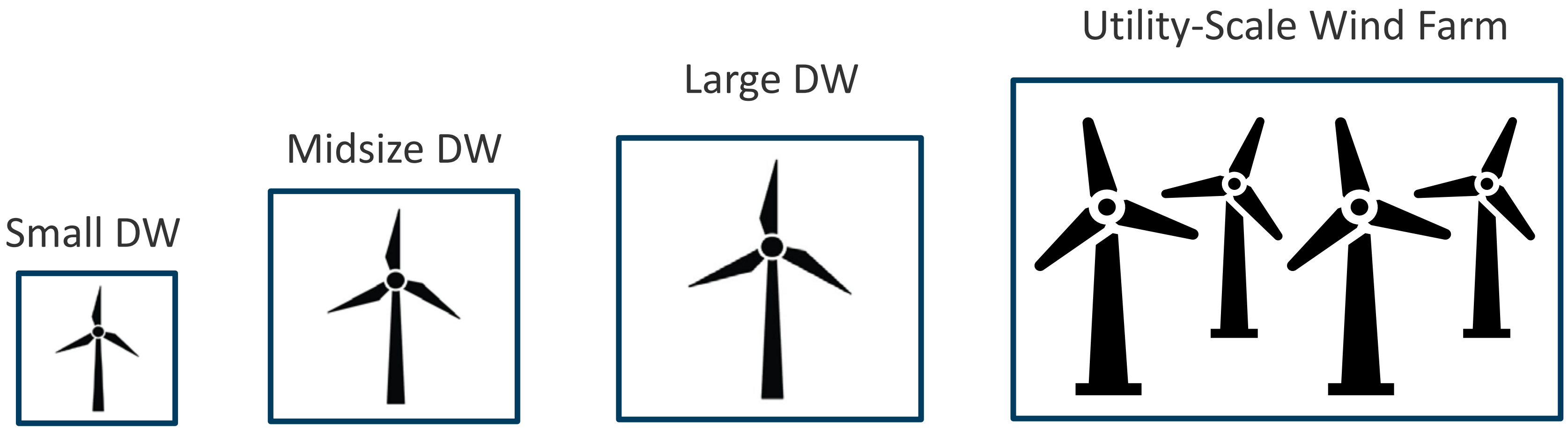
Agenda

1. Siting Considerations for DW
2. DW Zoning and Ordinances
3. Interconnection Considerations for DW

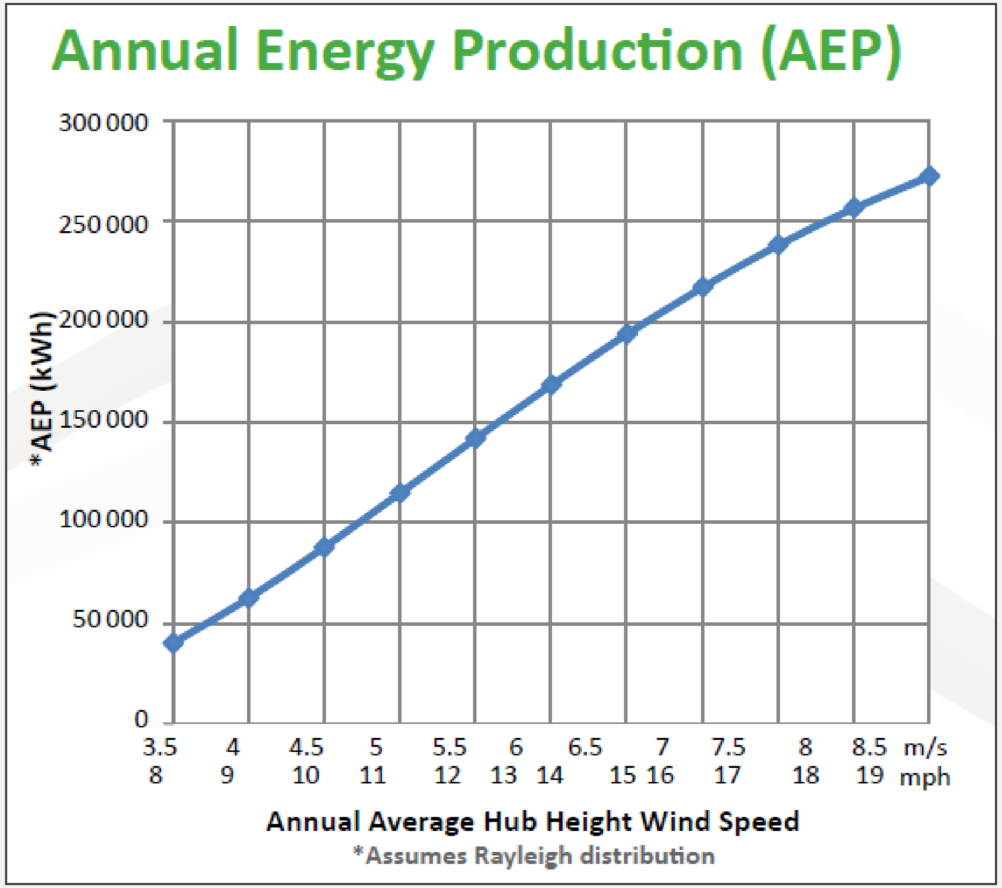
Siting Considerations for DW

DW Reminder: Turbine Size Varies



Capacity	≤100 kW	100-1000 kW	1 MW+	1 MW+
Height (ft)	30-160	78-250	200-320	320-574
Height (m)	10-50	24-75	58-98	98-175

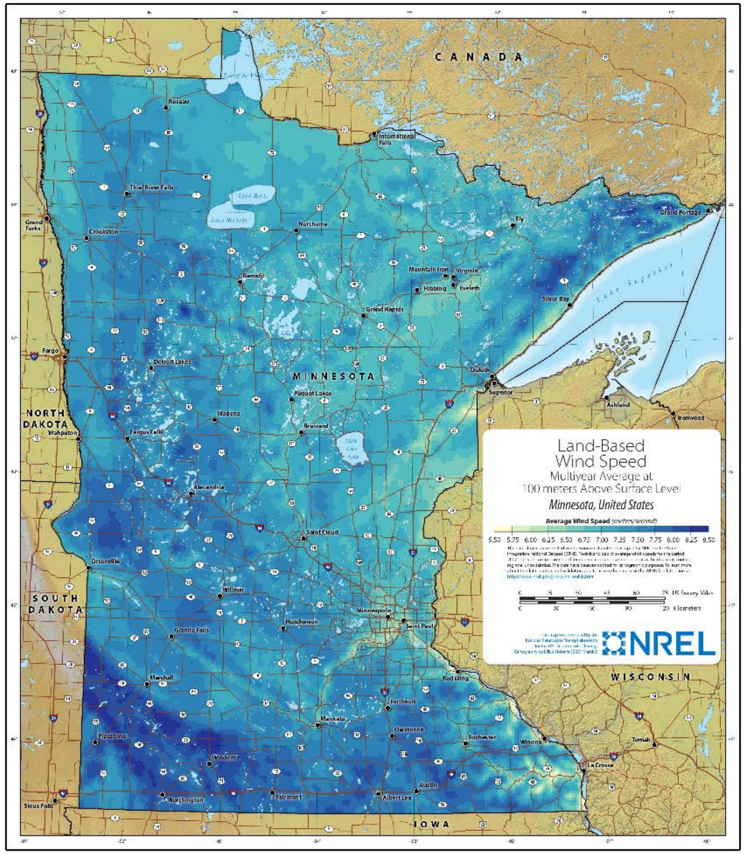
Wind speed and Production Increase as Project Height Increases

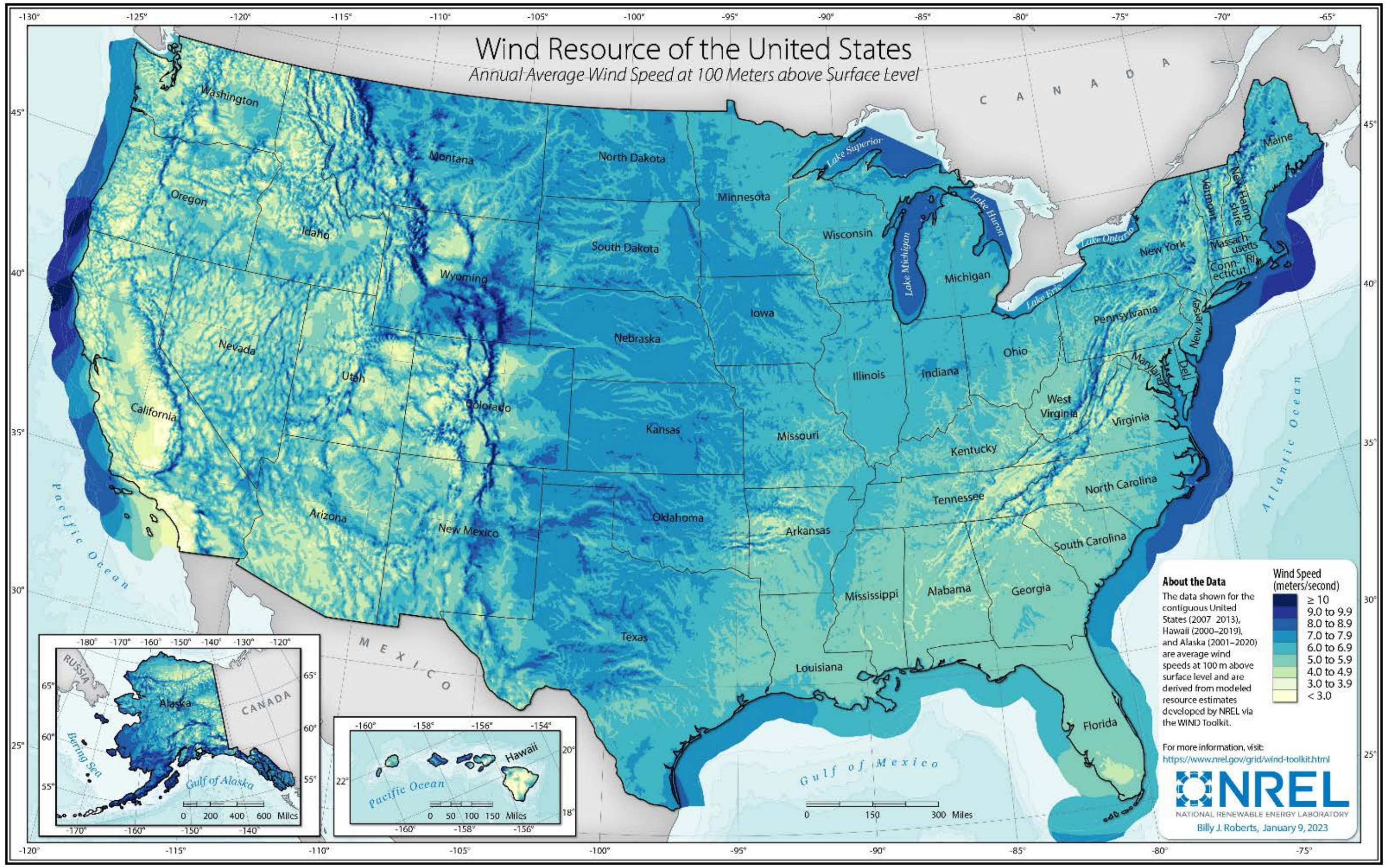


Annual Average Hub Height Wind Speed (m/s)	Annual Energy Production (kWh)
3.5	40 100
4.0	62 500
4.5	88 000
5.0	114 900
5.5	142 200
6.0	168 900
6.5	194 300
7.0	217 700
7.5	238 800
8.0	257 200
8.5	273 000

- Manufacturer’s specifications indicate approximate energy production per average wind speed.

Regardless of Turbine Size, a Strong Wind Resource Is Required

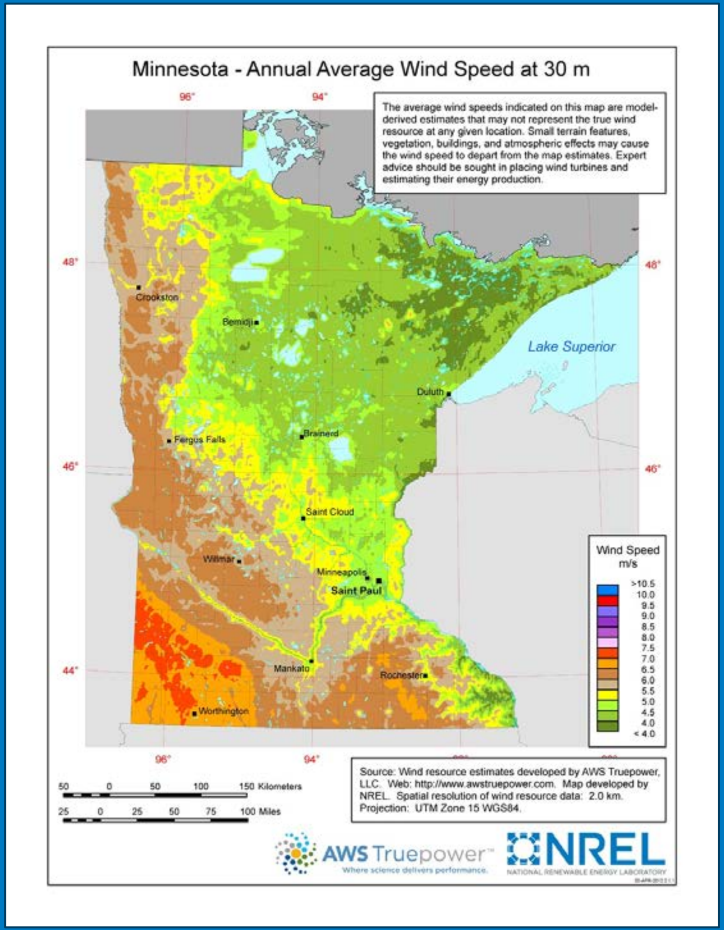


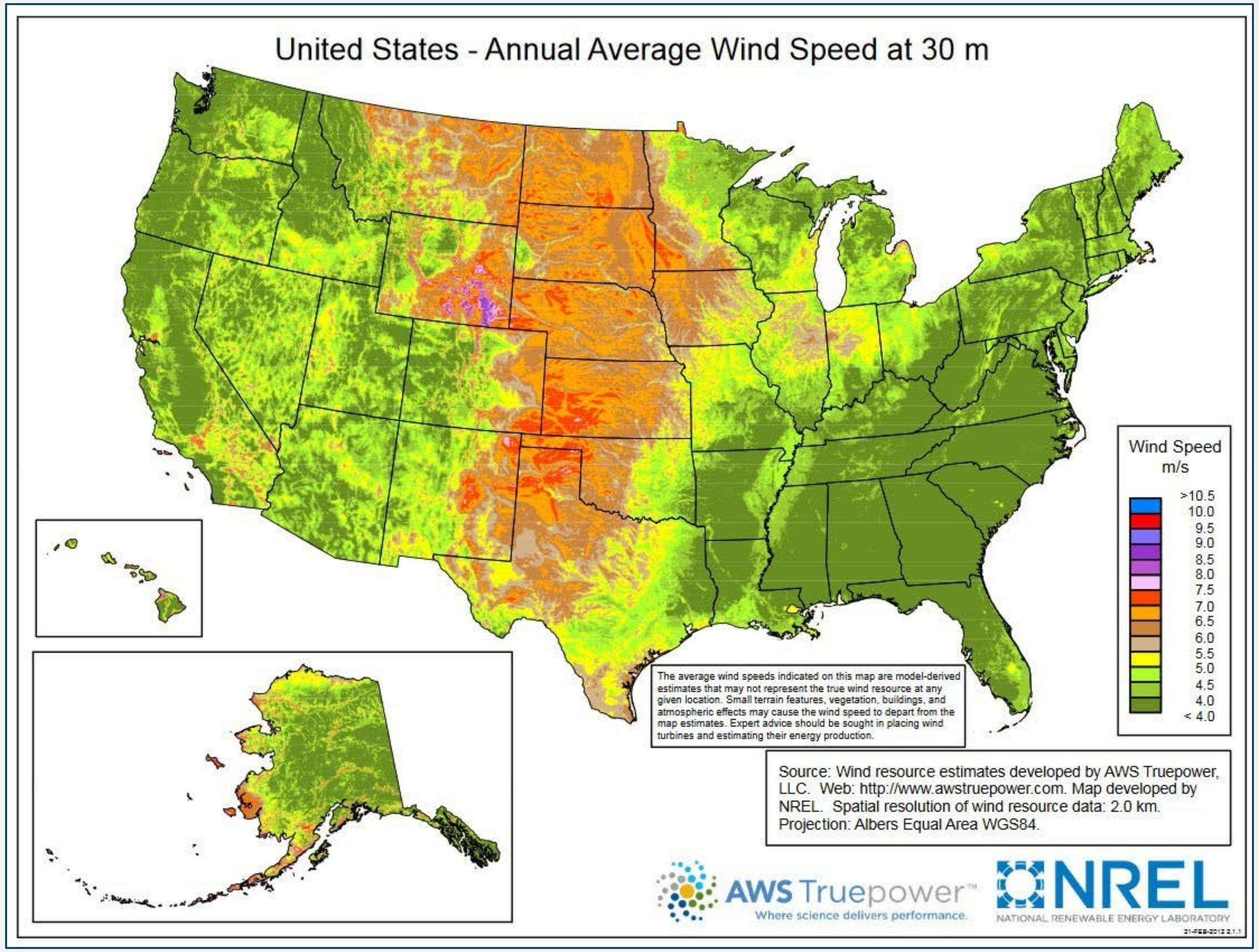


- For large wind turbines (greater than 1 MW), an annual average wind speed of at least **6.5 m/s at an 80 m** height is recommended.

Source: WINDExchange

Regardless of Turbine Size, a Strong Wind Resource Is Required





- For small wind turbines (up through 100 kW), an annual average annual wind speed of at least **4 m/s at a 30 m** height is recommended.

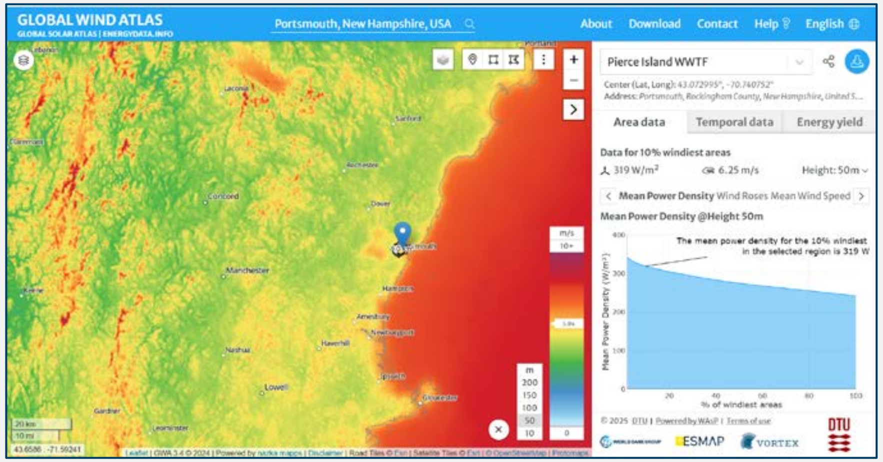
Source: WINDExchange

Tools Exist To Better Understand Wind Resource and To Estimate Performance

NREL's WindWatts

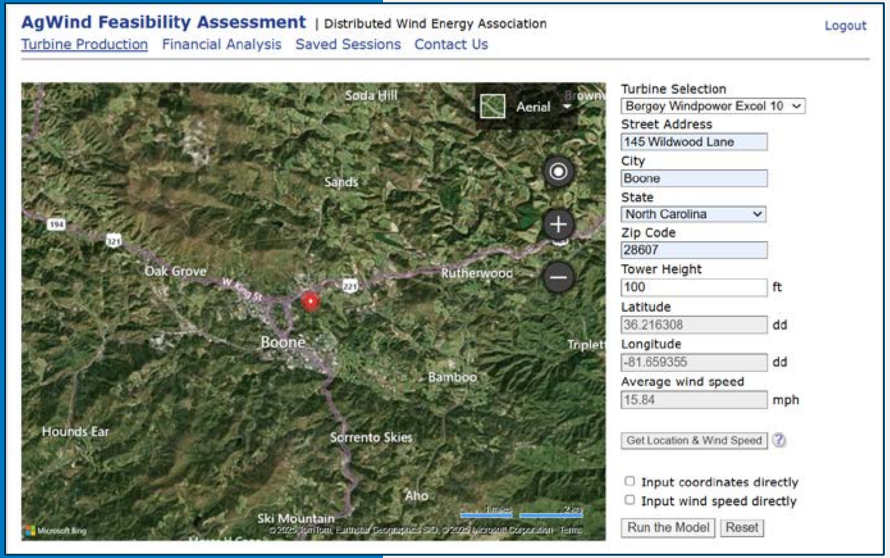
https://windwatts.nrel.gov/

Global Wind Atlas



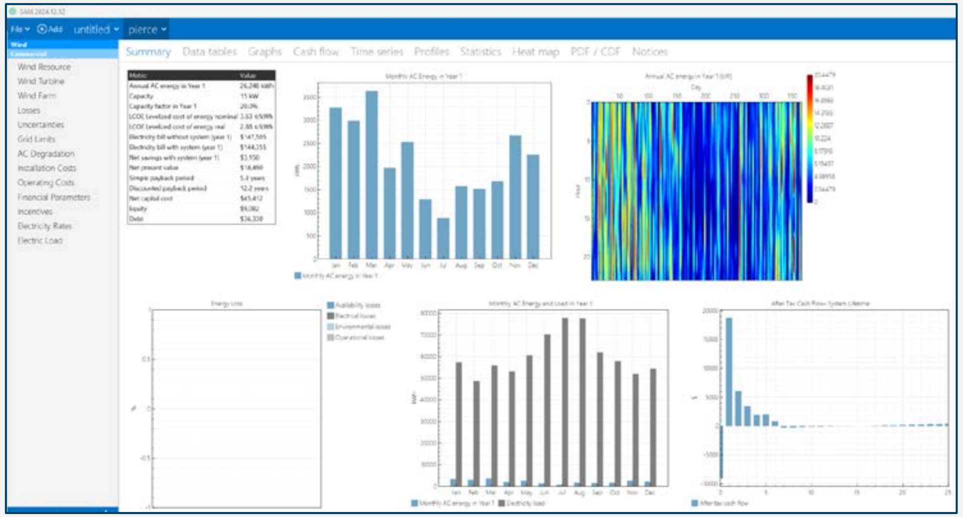
https://globalwindatlas.info/en/

AgWind Tool



https://agwindenergy.org

NREL's System Advisor Model (SAM)



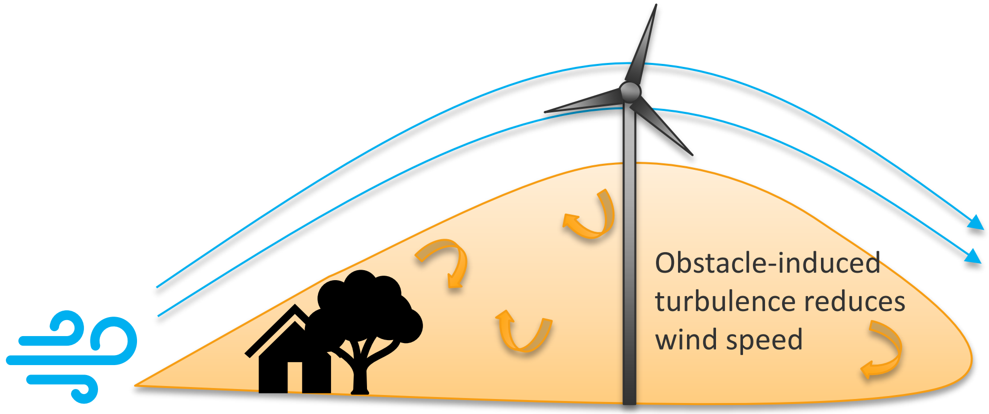
https://sam.nrel.gov/

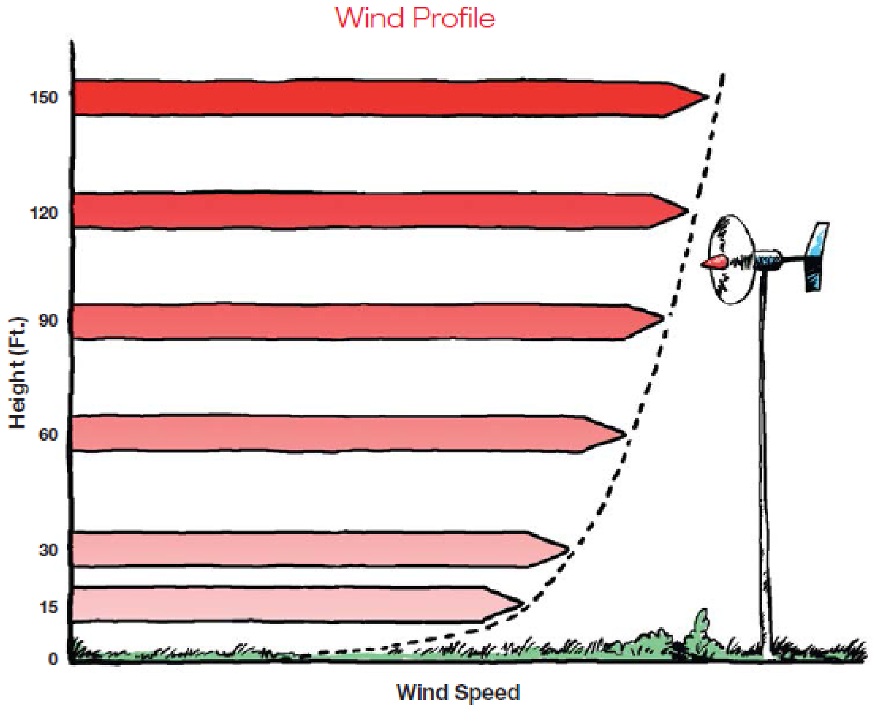
Siting Is Particularly Important in Complex Terrain

Northwind 100 in Boone, NC. Photo courtesy Nelson Aerials

- Increased uncertainty of wind resource estimates
- Avoid depressions
- Exploit ridges, higher elevations
- Make sure the towers are tall enough for turbines to clear surrounding obstacles

Tower Height Matters





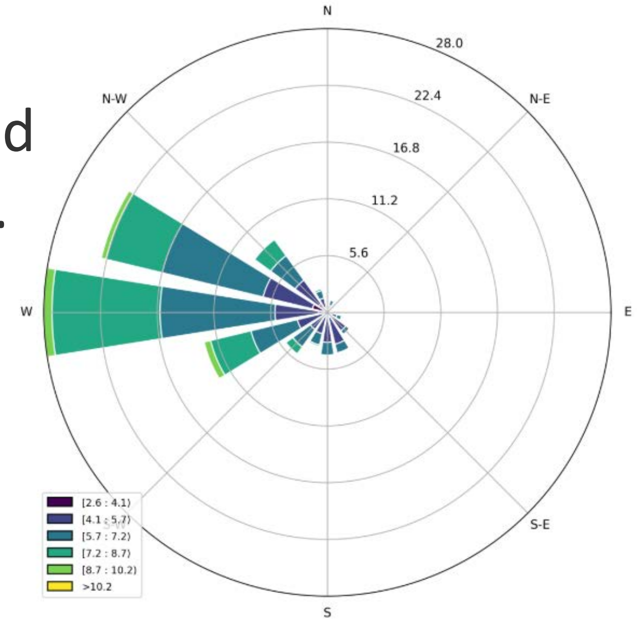
How tall do distributed wind turbine towers need to be?

- Wind speed increases with height above ground.
- 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).

Tower Height Matters

A poorly sited DW system. Courtesy of Brent Summerville.

- Entire rotor should be at least 30 ft. above anything within a 500 ft. horizontal radius.
- Too short of a tower is a long-term regret.
- Siting upwind of buildings and trees is preferred to mitigate turbulence.
- A wind rose can help understand the prevailing wind direction(s).



Wind rose from NREL's WindWatts

Land Use Varies, Depending on Number and Size of Turbines

Total land for multi-MW large wind project:
25 - 124 acres/MW

Large-scale installations with multiple turbines may occupy a large land footprint due to spacing requirements, but physically disturb little land.

- ~8 rotor diameters apart in prevailing wind direction
- ~4 rotor diameters apart in perpendicular direction
- Permanent land requirement: ~1 acre/MW
  - Includes direct impacts, such as wind turbine pads, access roads, substations, etc. that physically occupy land area and create impermeable surfaces.

Land Use Varies, Depending on Number and Size of Turbines

General rule for small DW: minimum of 1 acre is typically required.

Two, 100-kW turbines in Yuma, CO. Courtesy Northern Power Systems

For small-scale installations, land use impacts may be nonexistent or marginal.

- A **1 acre minimum** allows for setbacks from neighbors and property lines.
- Helps mitigate human environmental impacts such as noise and shadow flicker.
- Provides enough space for turbines to avoid obstacles (buildings, trees) that could cause turbulence.

Building-Integrated and Rooftop Installations Have Unique Considerations

Wind Turbines at Building 12 NASA Johnson Space Center. Courtesy of Mike vanBavel / Dynamax Inc.

Most built-environment turbines perform below expectations and are not recommended due to:

- Turbulent wind flow around buildings
- Causes under-performance and degrades turbine reliability
- Vibration and sound issues in buildings
- Higher cost due to complexities with installation and maintenance.

Turbine Size and Location Will Determine if a Project Will Impact Local Radar Systems

X-Band Radar Measurement installation near the King Plains Wind Farm, Garber, Oklahoma. Courtesy of Bryan Bechtold / NREL

- Small DW turbines are often not large enough to interfere with radar.
- Radar interference can be avoided by siting the wind turbine out of the line of the radar.
- The Federal Aviation Administration (FAA) reviews radar interference as part of its Obstruction Evaluation / Airport Airspace Analysis (OE/AAA) of tall structures (above 200’) that file a Notice of Proposed Construction with the FAA.

DW and Wildlife

Photo from Arterra / UIG via Getty Images

Photo from Edgar Figueiredo / Adobe Stock

Small wind turbines are less likely to cause wildlife impacts.

- Findings suggest that small residential turbines have limited impacts on avian mortality and behavior.
  - No turbine-related avian fatalities were recorded during a 2007-2012 study on small wind turbines in Maine (Morris and Stumpe 2015).
  - Distributed wind projects are more likely to be sited in already disturbed areas (manufacturing complex or agricultural field).
  - The U.S. Fish & Wildlife Service Land-Based Wind Energy Guidelines provides a tiered approach for assessing potential wildlife impacts and does not expect distributed wind projects to need to go beyond preliminary site evaluations.
- Although wind-wildlife impacts are more common for large-scale wind projects, regardless of project size, micro-siting is critical to mitigating potential impacts.

DW Zoning and Ordinances

State and/or Local Zoning Ordinances Are Often Divided Into Regulations for Small (Accessory Use, On-Site) and Large (Commercial, Utility-Scale) Wind

These regulations play an essential role in mitigating local impacts by establishing:

- Zoning districts for development
- Capacity limitations
- Height limitations
- Setback limitations
- Sound limitations
- Shadow flicker limitations
- Decommissioning standards.

Districts for Development

- Small DW turbines are often allowed as permitted use, or conditional use, in most zoning districts.
- Still, some communities prefer to restrict small DW from residential districts.
- Large DW turbines are often allowed as conditional use, or special use in a smaller selection of zoning districts that may not include residential, floodplain, shoreline, or historical districts.

Capacity Limitations

	Capacity per turbine
More restrictive	Less than 20 kW
	Less than 40 kW
	Less than 50 kW
Less restrictive	**Less than 100 kW**

- Establishes an upper threshold for small DW and a lower threshold for large wind.
- Less than 100 kW is the industry’s definition for small wind.

Height Limitations

	Height
Less inclusive	Up to **66 feet** in height (does not define whether it's total height or hub height)
	Less than 80 feet total height (includes blades)
	100 feet total height (includes blades)
	Less than 100 ft hub height
	Less than **150 feet** tall at highest point
	Less than 200 ft
More inclusive	"No limitation on system height, except as imposed by FAA regulations and the required setbacks"

- Typically defined as total height (from base of tower to tip of blade in highest position).
- Example on left focused on small DW.
- Height limitations can also impact large DW.
- Turbine limitations 500 ft. and below can exclude modern turbines that can have a total height of more than 650 ft.

Setback Limitations

- Intended to create minimum safety standards between wind turbines and areas of concern, like:
  - Property lines
  - Neighboring structures
  - Inhabited structures
  - Railroad
  - Wetlands
  - Public roads
  - Public lands
  - ROW for overhead transmission
  - ROW for overhead or distribution lines.
- Can be fixed distance or ratio/multiplier.
- Setbacks based on ratio/multiplier increase as turbine height increases.
- Utility-scale wind farm setbacks should not apply to distributed wind.
- Some communities use setbacks to reduce viewshed and other impacts.
- Can be a de facto moratorium if too limiting.

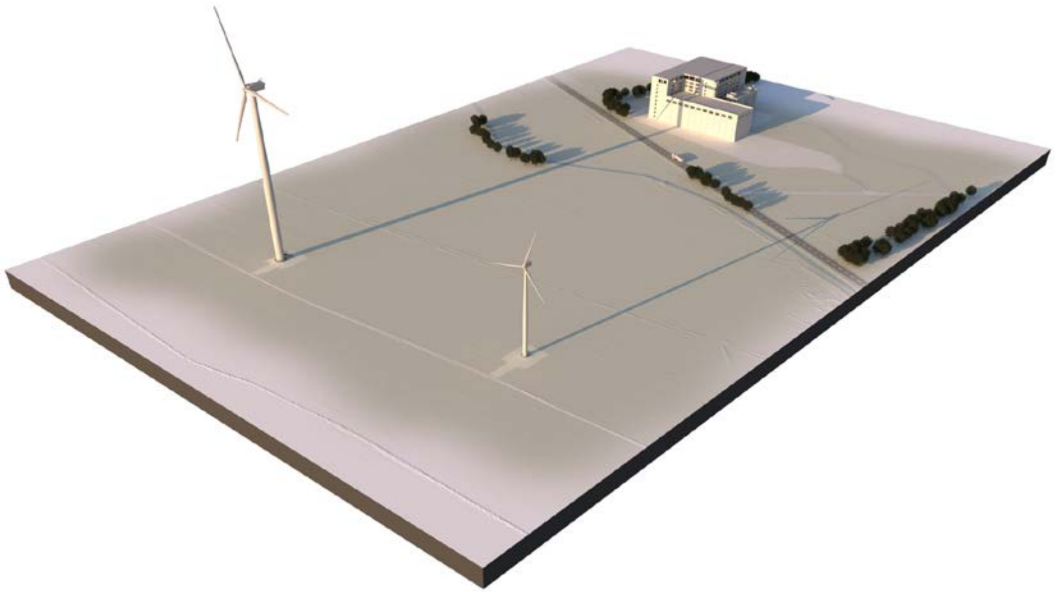
Neighboring Structures	Property lines
150 feet	1 foot for every 1 foot of tower height
500 feet	1x total height
750 feet	1.1x total height
1.1x total height	1.15x total height
1.5x total height	1.5x total height

Sound Limitations

	Sound
More restrictive	30 dBA
	The average sound level from a SWES shall not exceed fifty-five 55 dB(A) during daytime hours or forty-five (45) dB(A) during nighttime hours at any point within neighboring, residentially zoned or used property. For neighboring industrial properties the sound level limit is sixty-five (65) dB(A) and for other neighboring nonresidential properties, the sound level limit is sixty (60) dB(A) at any time of the day. 2) Five (5) dB shall be added to the average sound level from a SWES as a penalty when its sound emissions have an adverse character that includes prominent tones (e.g., a humming sound) or an amplitude fluctuation in synchronicity with the blade revolution (e.g., a periodic swishing sound). 3) No SWES shall operate with an average sound level more than 5 dB(A) above the non-operational ambient level, as measured within any neighboring residentially zoned or used property. 4) To limit the level of low-frequency sound, the average C-weighted sound level during SWES operation shall not exceed the A-weighted ambient sound level by more than twenty (20) dB. 5) Sound level meters used for sound measurement must be a Type 2 or better grade per ANSI S1.4 and must have an integrating feature that meets ANSI S1.43. Procedures must meet the applicable portions of ANSI S12.9. Measurements must be made when ground level winds do not exceed 5 mph.
	All WECS shall comply with Minnesota rules 7030 (50 dBA)
Less restrictive	60 dBA

- Can be measured from property line or neighboring dwelling.
- Modern distributed wind turbines that are sited ~ 200 ft. away typically operate at an ambient sound level of around 55 decibels (dBA).
- Additionally, some modern turbines have features that can help control sound emissions such as:
  - Insulation of the nacelle and gearbox
  - Blade serrations.
- It is recommended that turbines are held to existing sound ordinance standards, with exceptions for short-term events like severe windstorms or utility outages.

Shadow Flicker Limitations



- Occurs when rotating wind turbine blades cast shadows on the ground (including roads) or on nearby structures, usually at sunrise and sunset.
- More of an issue with large turbines than small DW.
- There is no strong epidemiological evidence linking shadow flicker to serious health effects.
  - Studies revealed turbines are unlikely to induce an epileptic response (Knopper and Ollson 2011).
- Computer models can accurately predict when, where, and to what degree shadow flicker will occur.
  - Wind project developers can mitigate flicker impact during site selection.

Shadow Flicker Limitations

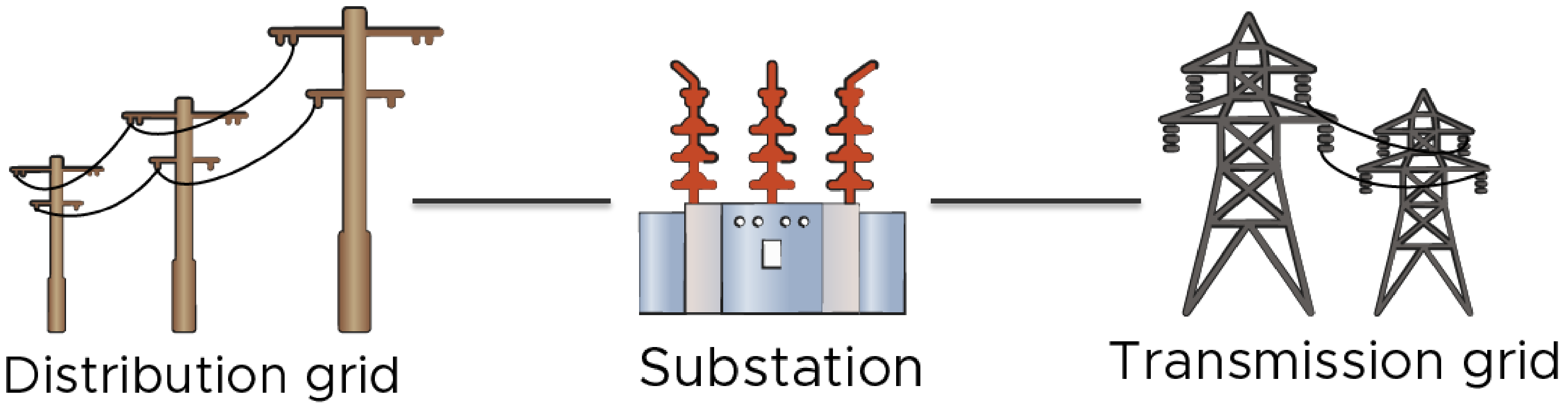
	Shadow flicker
More restrictive	The on-site WECS shall be located and designed such that shadow flicker will not fall on, or in, any existing residential structure.
	A flicker analysis shall include the duration and location of flicker potential for all receptors and roadways within a one-mile radius of each turbine within a project. The applicant shall provide a site map identifying the locations of shadow flicker that may be caused by the project and the expected durations of the flicker at these locations from sunrise to sunset over the course of a year. **Flicker at any receptor shall not exceed 30 hours per year within the analysis area.**
	Intermittent shadow or flutter shadow shall not be cast on any adjacent residence more than a total of 10 minutes a day.
Less restrictive	The SWES facility shall be sited such that shadow flicker will not fall on any existing residential building of a nonparticipating property within 500 feet of the SWES property for more than one hour a day.

Decommissioning Standards

- Primarily involves regulations related to project removal, including:
  - Duration of inoperability before turbine must be removed
  - Removal requirements for below ground infrastructure (cables and foundation)
  - Removal timeline
  - Decommissioning plans
  - Decommissioning bonds
  - Site restoration.
- Communities often allow option to apply for extensions if the owner wants to re-power the project.
- Bonds, plans, belowground infrastructure removal, and site restoration are often required as part of large wind projects and may not be applicable for small DW.

Interconnection Considerations for DW

The Distribution System

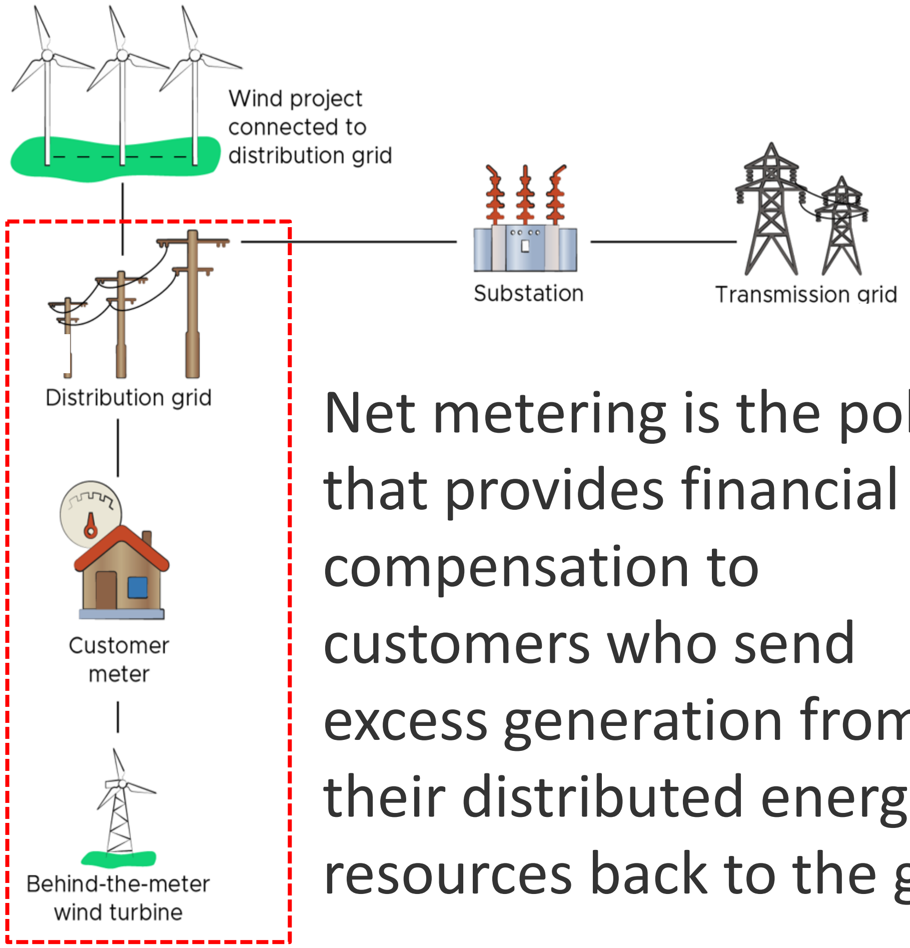


- A distributed wind energy project is connected at the distribution level of an electricity delivery system (or off-grid).
- A distribution system is on one side of a substation that is connected to a larger transmission system.

Interconnection Type: Behind-the-Meter

Most distributed wind projects that provide electricity for on-site consumption are behind-the-meter installations.

Behind-the-meter means the turbine is connected to the local distribution grid behind the customer's utility meter. Excess generation may go back to the grid through net-metering or other billing mechanisms.

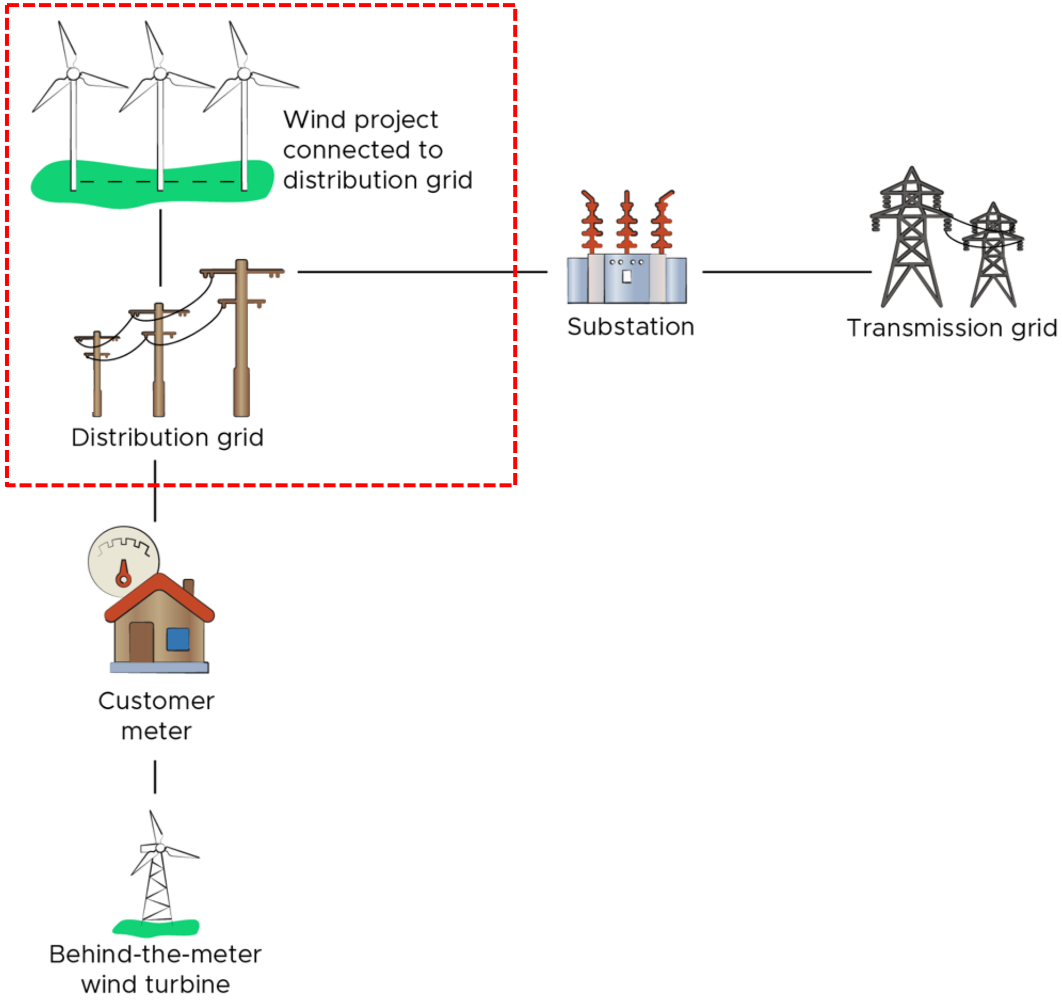


Net metering is the policy that provides financial compensation to customers who send excess generation from their distributed energy resources back to the grid.

Interconnection Type: Front-of-the-Meter

Front-of-the-meter means the distributed wind is connected to the distribution grid to serve loads interconnected to the same distribution grid.

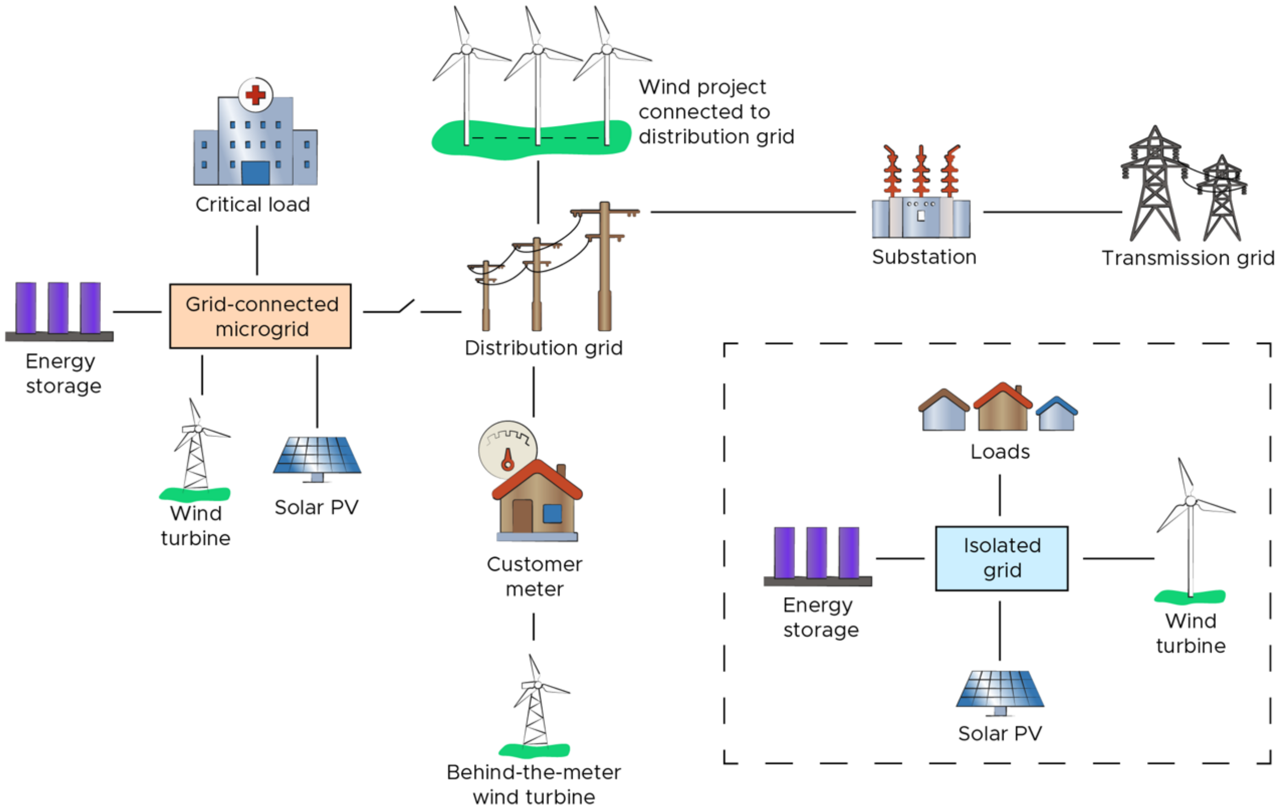
Front-of-the-meter systems do not serve one specific facility but contribute power to the grid.



Interconnection Type: Microgrid

Distributed wind can also be part of grid-connected microgrids…

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.

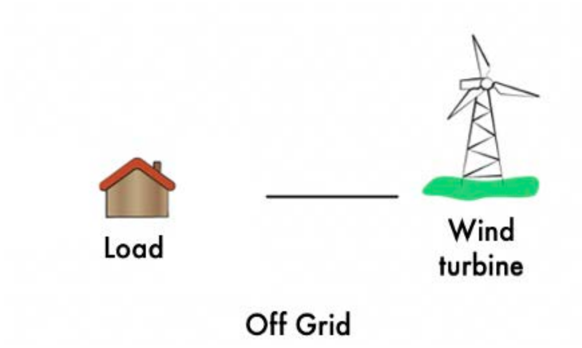


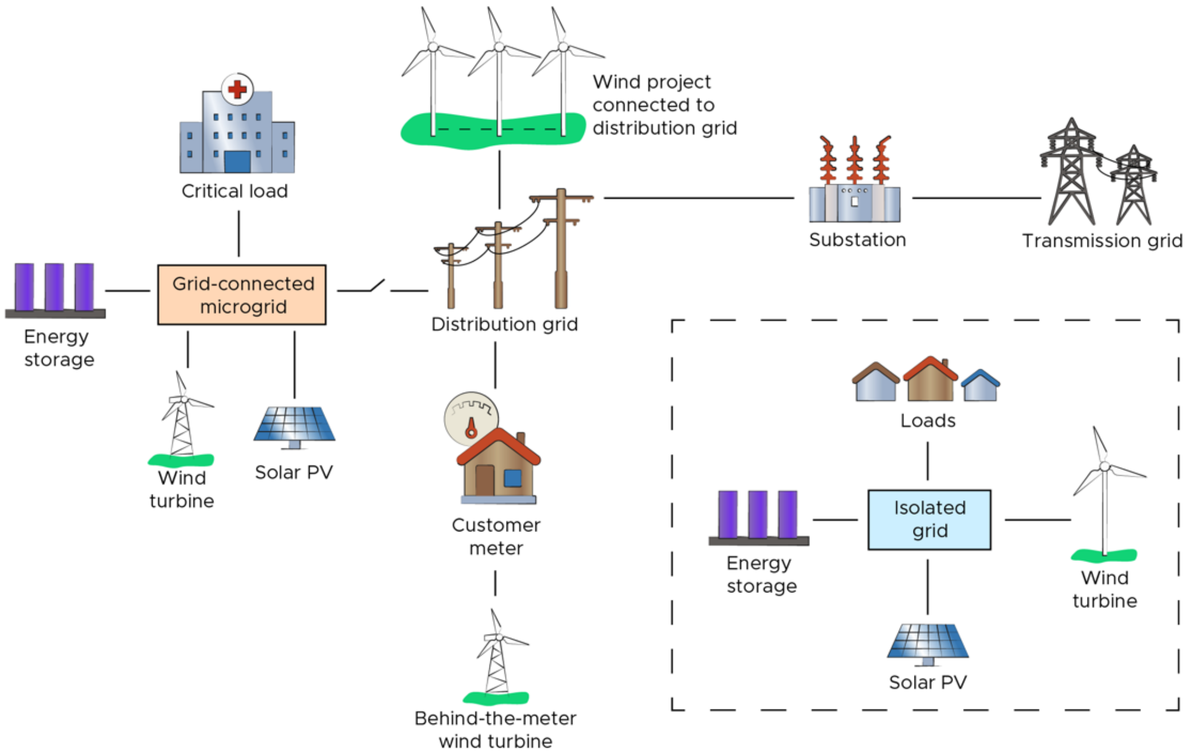
…and isolated microgrids, such as for a remote village not connected to any other grid system.

Interconnection Type: Off-Grid

A wind turbine can also be off-grid in a remote location for an on-site energy need.

This is still considered distributed wind, but it is not connected to the local distribution grid.





We differentiate off-grid from an isolated microgrid. Off-grid applications tend to power just one load, while an isolated microgrid is typically for a broader set of loads.

Thank you!

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