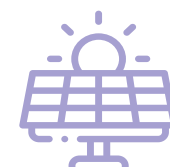
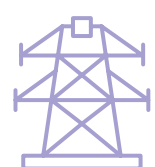




**INDUSTRY
OVERVIEW
SEGMENTS**

WIND



INDUSTRY OVERVIEW SEGMENT – WIND

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Industry Overview

MARKET SIZE & GROWTH FORECASTS

- **Installed Capacity:** As of 2023, the U.S. has over 140 gigawatts (GW) of installed onshore wind capacity, making it one of the largest markets globally. Globally, there is approximately 900 GW of installed onshore wind energy.
- **Market Value:** The U.S. wind turbine market is estimated to be valued between \$30 billion and \$50 billion, encompassing not just turbine manufacturing but also installation, maintenance, and related services. Globally, this market is valued between \$100 - \$150 billion.
- **Future Expansion:** The market is expected to grow at a compound annual growth rate (CAGR) of around 8-10% over the next several years. By 2030, the installed capacity could exceed 200 GW in the United States. The United States is seeing slightly higher expected growth rate – however this is partly due to the United States lagging in installed capacity.
- **Investment Trends:** Continued investment in wind energy, driven by federal and state policies promoting renewable energy, is expected to sustain growth.
- **Leading States:** Texas, Iowa, Oklahoma, and Kansas are among the states with the highest installed wind capacity, benefiting from favorable wind resources and supportive policies.
- **Emerging Markets:** States in the Southeast and Northeast are beginning to ramp up their wind energy projects, contributing to overall market growth. Utilizing a hybrid system including wind turbines along with other renewables is a growing trend to help reduce intermittency issues.
- **International Markets:** Beyond the United States, China, and Europe (especially Germany and Spain) are key players in the onshore wind turbine market, accounting for a significant share of the global installed capacity. Growing markets include countries in Asia, Latin America, and parts of Africa are

MARKET DRIVERS

- **Government Support:** Federal tax incentives, such as the Production Tax Credit (PTC) and Investment Tax Credit (ITC), play a crucial role in driving investments.
- **Environmental Goals:** Increasing commitments to reduce carbon emissions and promote renewable energy sources enhance the attractiveness of wind energy.
- **Technological Advancements:** Innovations in turbine design and efficiency continue to make wind energy more competitive compared to fossil fuels.

CHALLENGES & CONCERNS

- **Intermittency:** Wind energy production is variable, leading to challenges in energy storage and grid integration.
- **Regulatory Hurdles:** Permitting and regulatory processes can be lengthy and complex, affecting project timelines and costs.
- **Social license to operate:** public concern over decreased property values, long term disposal of equipment, and viewshed impacts.
- **Environmental concerns:** negative impacts on bat, birds, and other animals warrants more studies. Operational noise is a concern for residents near the operating turbines.
- **Land use:** larger renewable systems are competing for farmland or land designated for future economic growth markets.

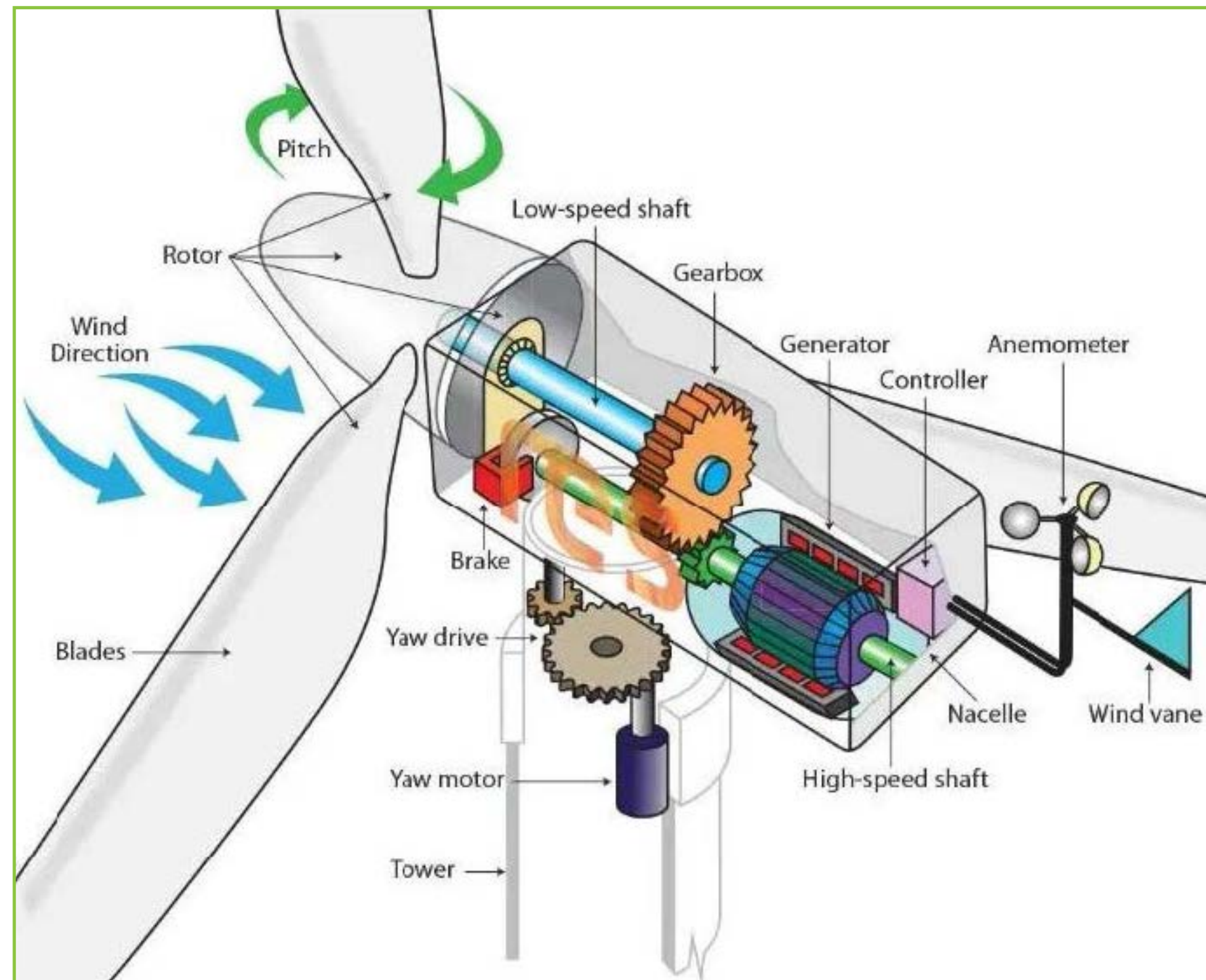
FUNDING OPPORTUNITIES

The US Department of Energy's Manufacturing and Energy Supply Chains (MESC) office serves as the frontline of America's energy manufacturing deployment and supply chain security. Their mission is to enhance economic and national security by eliminating vulnerabilities in the United States' energy supply chains.

The MESC offers competitive grant opportunities for small to medium sized manufacturers that focus on manufacturing expansion and workforce training. Efforts span battery storage, grid components, critical minerals processing and recycling, energy generation, nuclear power, buildings and energy efficiency, transportation, and industrial materials. Funding opportunities are announced periodically throughout the year. The office also publishes reports on supply chain needs, market opportunities, guidance documents, and factsheets.

<https://www.energy.gov/mesc/office-manufacturing-and-energy-supply-chains>

Current funding opportunities: <https://www.energy.gov/mesc/funding>



Turbine Components

TOWER

Wind turbine towers reach from the foundation to the nacelle, allowing the rotor to access high wind speeds far above ground level. Turbine towers are made of tubular steel to successfully support the weight of the nacelle, hub, and blades. In the United States, utility-scale, onshore wind turbine towers reach an average of over 100 meters (328 feet), particularly in the Midwest and Northeast. For this massive section of the turbine to be successfully transported and assembled, the tower is typically manufactured in three sections. A wind construction company will assemble the tower and other major parts on-site at the wind farm, using heavy-duty cranes.

NACELLE

The nacelle houses the mechanical components needed to convert the rotation of the turbine blades into energy – also known as the drivetrain. From a distance, the nacelle may seem like a relatively small section of a wind turbine, especially when compared to the tower and turbine blades. However, this part of a wind turbine can weigh over 50 tons (100,000 lbs). Transporting nacelles requires special equipment for supersize loads, as normal flatbed trailers do not have the capacity to handle that weight.

GEARBOX

The gearbox helps to convert the relatively slow rotational speed of the turbine rotor to the high speeds needed to run the generator. The rotor achieves around 18 revolutions per minute (rpm), while the generator will need around 1,800 rpm to successfully generate electricity. The gearbox connects the rotor hub to the generator by a series of drive shafts.

DRIVE SHAFTS

The turbine's drive shafts are integral parts of the drivetrain, working in conjunction with the gearbox to increase rpm and run the generator. The low-speed shaft (also known as the main shaft) connects the hub to the gearbox. A smaller, high-speed shaft connects the gearbox to the generator.

GENERATOR

The generator is ultimately what converts wind power to electrical energy by means of electromagnetic induction. Wind energy is an increasingly popular renewable energy source because it does not require mining or digging for fossil fuels, instead running on an endless supply of kinetic energy provided by the wind. It's also a "clean" form of energy that doesn't burn fossil fuels or release carbon emissions.

HUB

The hub is part of the rotor, securing the three blades and connecting them to the drive shaft in the nacelle. The hub has a cast iron structure weighing between 7 and 14 tons (14,000–28,000 lbs), as it needs to be sturdy enough to support the weight of the turbine blades. Wind turbine hubs have an average length of 4–6 meters (13–20 feet), and a diameter of 3–4 meters (10–13 feet). Wind turbines are often measured in terms of "hub height," which refers to the distance from the ground to the center of the hub.

YAW SYSTEM

The yaw system underneath the nacelle is responsible for orienting the turbine according to wind direction (determined by the wind vane and anemometer). The yaw drive and yaw motor work together to adjust the nacelle so it captures wind power as effectively as possible. This system is crucial for maximizing the value of the turbine and keeping the generator running at a more constant rate.

BLADES

Blades for onshore, utility-scale turbines in the U.S. average between 200–300 feet long – and they're consistently being manufactured at larger sizes to achieve a higher power output. Turbine blades are adjusted by the "pitch system," which is based on wind speeds. The pitch system helps turn the rotor at an optimum speed – ensuring that high winds that are too strong don't damage the turbine.

Modern turbine blades are primarily made of aerodynamic fiberglass and are hollow. These factors make turbine blades lighter than the steel tower and even the nacelle – but they still weigh several tons at least, and their sheer size poses significant logistical challenges.



Components of Typical Onshore Wind Turbine

COMPONENT	NAICS		DESCRIPTION	USE
Bearings	332991	Ball and roller bearings	A number of bearings are required for the shafts, gearbox, yaw mechanism, generator, and other rotating parts.	A four-point contact ball bearing joins the nacelle and the tower, allowing the nacelle to slew about in order to face upwind and extract the maximum amount of energy from the wind. The main shaft rotates on large tapered roller bearings, or in some cases a large spherical bearing.
Blade Extender	331511	Iron foundries	These steel components serve as a means to support the rotor blades and secure them to the hub.	Typically weighing over a ton, each blade extender is mounted to a four-point ball bearing, which is then mounted to the hub. The structure of the extenders allows each blade maximize rotation while connected to the pitch mechanism.
Brakes	33613	Power Transmission Equip.	Mechanical brakes are used as auxiliary devices to insure that the rotors, gears and generator have stopped during maintenance or periods of inclement weather.	The yaw mechanism typically halts any blade rotation by turning the rotors perpendicular to the wind direction. Should the rotors continue to turn, many turbines are equipped with either hydraulic or spring activated brake systems to prevent undesired rotation or fatigue on the turbine.
Cooling system	333412	Axial fans	A large fan drives air to convectively cool the generator and gearbox and exhausts waste heat from the nacelle assembly. Ducting directs cool air to the generator.	Most wind turbines have cooling and dehumidifying units set to maintain conditions within the nacelle at levels such that rust and corrosion is largely prevented.

COMPONENT	NAICS		DESCRIPTION	USE
Coupling	333613	Power Transmission Equip.	The flexible coupling attaches to the high speed shaft and dampens out oscillating loads introduced by the gearbox. The reduction of these loads improves the quality of the electricity produced by the generator.	Modern couplings make use of composite materials for increased strength and flexibility. Use of these materials will increase and lighten the weight in a typical wind turbine
Electronic Controller	334418	Printed circuits and electronics assemblies	The communications subsystem allows the wind turbines to monitor themselves and report performance to a control station. The controller also adjusts blade pitch and turbine yaw to adapt to wind conditions.	Although there are typically controllers at the top and bottom of a tower, the increased data transfer capabilities of fiber optic wiring have provided the opportunity for a third controller to be placed in the hub of the rotor. The additional controller usually communicates with the nacelle unit using serial communications through a cable connected with slip rings and brushes on the main shaft
Gear Box	333612	Speed changer, industrial	The gearbox employs a planetary gear system to convert low-speed rotation of the input shaft from the rotor to high-speed rotation which drives the high-speed shaft of the generator assembly.	The gearboxes for larger wind turbines are more expensive per kilowatt (kW) of rated power than for smaller turbines because the torque increases more quickly than the power when increasing the rotor diameter. Hence, gearboxes have become one of the more expensive, critical components of a modern, utility-scale wind machine.
Generator	333611	Turbines, and Turbine Generators, and Turbine Generator Sets	This system converts high-speed shaft work into electrical energy by spinning the rotor around the magnetic stator and using the electromagnetism to produce AC electricity.	Most modern wind turbines employ a doubly-fed, or induction, generator, which uses an electromagnet for both the stator and rotor magnets. This allows the generator to “slip” relative to the phasing of the electric grid, which both allows the wind turbine to operate at variable speed, as well as providing “reactive power” a feature which many utilities desire. However, this requires the use of power electronics to condition the generator output.
Hub	331511	Iron Fpoundries	The hub serves as a base for the rotor blades and extenders, as well as a means of housing the control systems for the pitch drive. It rotates freely and attaches to the nacelle using a shaft and bearing assembly.	The hub is often cast as a single steel part.

COMPONENT	NAICS		DESCRIPTION	USE
Nacelle Case	326199	All Other Plastics Product Manufacturing	The nacelle case encloses all of the major mechanical components of the wind turbine.	The nacelle casing is composed of glass fiber-reinforced plastic with steel reinforcements. Through rubber dampers, the casing is mounted to the main frame with steel supports.
Nacelle Frame	331511	Iron foundries	The nacelle frame is a steel bed to which all of the major components are bolted.	Numerous holes are drilled into the frame of the nacelle for stability reasons. While the largest hole allows maintenance entry through the bottom of the nacelle, the other holes are precisely placed in order to ensure that the frame will not vibrate in step with the other components of the turbine. The nacelle frame is a single cast steel piece.
Pitch Drive	335312	Motors and Generators	This system controls the pitch of the blades to achieve the optimum angle for the wind speed and desired rotation speed.	For variable-pitch wind turbines, a drive system is used to change the pitch of the blades to vary power output, and at high wind speeds to divert excess energy, thus reducing stress on the blades and keeping rotational speeds within design specifications. There are typically three motors used to perform this function, one for each blade. A hydraulic power package in the nacelle provides the power, and in case of power failure, a hydraulic accumulator provides backup power for the system. Fully-electric pitch drives may also be employed.
Power Electronics	335999	Electronic Equipment and Components, NEC	The power electronics match up the generator's output power with the electric grid.	With an induction generator (used in most modern wind turbines), the phase of the generator output must be synchronized to the phase of the utility grid. The power electronics do this by converting the AC signal from the generator to DC, and then re-inverting the DC back to AC at the correct phase.
Rotor Blade	326199	All Other Plastics Products Manufacturing	Rotor blades convert the energy of the wind to mechanical energy by harnessing the principles of lift. Blades can have a stall regulated or variable-pitch design	Currently the majority of blades are made of glass fiber-reinforced plastic. The profile of the blade is carefully designed to maximize lift over the entire length of the blade, while still providing structural integrity in maximum wind conditions.

COMPONENT	NAICS		DESCRIPTION	USE
Sensors/Data Loggers	334519	Measuring and Cooling Devices	Sensors throughout turbines relay information to the electronic controllers, which automatically adjust turbine components to address changing conditions.	A wind vane measures wind direction and relays data to the yaw mechanism, a cable twist counter monitors cables within the tower to determine if the turbine has been yawing in one direction for an extended period of time, the anemometer measures wind speed. Additionally, a thermocouple senses temperature within the nacelle and a vibration sensor monitors vibration to detect potential component failure.
Shafts	33613	Power Transmission Equip.	The low speed shaft connects the rotor to the input of the gearbox, and the high speed shaft connects the output of the gearbox to the generator.	The sizes of shafts have significantly decreased as component parts such as bearings have become smaller. Therefore, greater fatigue on smaller shafts has necessitated better handling of fatigue and possibly more regular maintenance.
Tower Flange and Bolts	331511	Iron Foundries	These components join tower segments.	A combination of bolting and welding is employed to join flanges and tower segments. To assure the stability of the tower welding seams, x-rays inspections are made of the adjoining segments
Towers	332312	Fabricated Structural Metal	This large component of the turbine is made of rolled, tubular steel, and built in sections because of its size. For tubular towers, the most common type, a ladder is built in the hollow center to provide maintenance access.	The size, both diameter and height, of the tower are restricted by transportation requirements.
Yaw Drive	335312	Motors and Generators	The yaw drive slews the turbine directly into the wind in order to generate maximum power. Typically, four yaw drives monitor the wind direction and active the yaw motors to face the prevailing wind.	When the wind blows over 60 mph the mechanism turns 90 degrees from prevailing winds to reduce stress on internal components and to prevent stalling due to over-speed conditions.

Adapted from Renewable Energy Policy Project, October 2005



Wind Turbine Developers and Manufacturers

GE Vernova: A major player in the U.S. wind market, GE designs and manufactures a range of wind turbines for both onshore and offshore projects.

Vestas: A leading manufacturer with a strong presence in the U.S. market, focusing primarily on onshore wind energy.

Siemens Gamesa Renewable Energy: Actively involved in both onshore and offshore wind projects across the U.S., providing turbines and services.

Nordex USA: Part of the Nordex Group, this company manufactures and develops onshore wind turbines tailored for the U.S. market.

EDP Renewables (EDPR): Operates numerous wind farms across the U.S. and focuses on the development of renewable energy projects.

- [Supplier portal](#)

Invenergy: A developer and operator of renewable energy projects, including a significant portfolio of wind farms in the U.S.

NextEra Energy Resources: A subsidiary of NextEra Energy, this company is one of the largest developers of wind and solar projects in the U.S.



Wind Turbine Trade Association & Resources

American Wind Energy Association (AWEA) - Now part of the U.S. Wind Energy Association, it is the primary national trade group representing the wind industry, focusing on advocacy, education, and industry standards.

National Renewable Energy Laboratory (NREL) - NREL conducts extensive research and provides data that supports the wind industry, influencing policy and development.

Wind Energy Foundation - This organization promotes the benefits of wind energy and supports policy initiatives to advance wind energy development.

Clean Power States Alliance (CPSA) - A coalition of states and organizations that advocates for clean energy, including wind, focusing on policy and program development.

American Clean Power Association (ACP) - Represents the renewable energy sector broadly, including wind, and advocates for policies that promote clean energy growth.

Pennsylvania Wind and Solar: An advocacy group that promotes the development of wind and solar energy in the state.

Ohio Wind Working Group: A coalition that focuses on promoting wind energy development in Ohio, providing resources and information about the benefits of wind power.

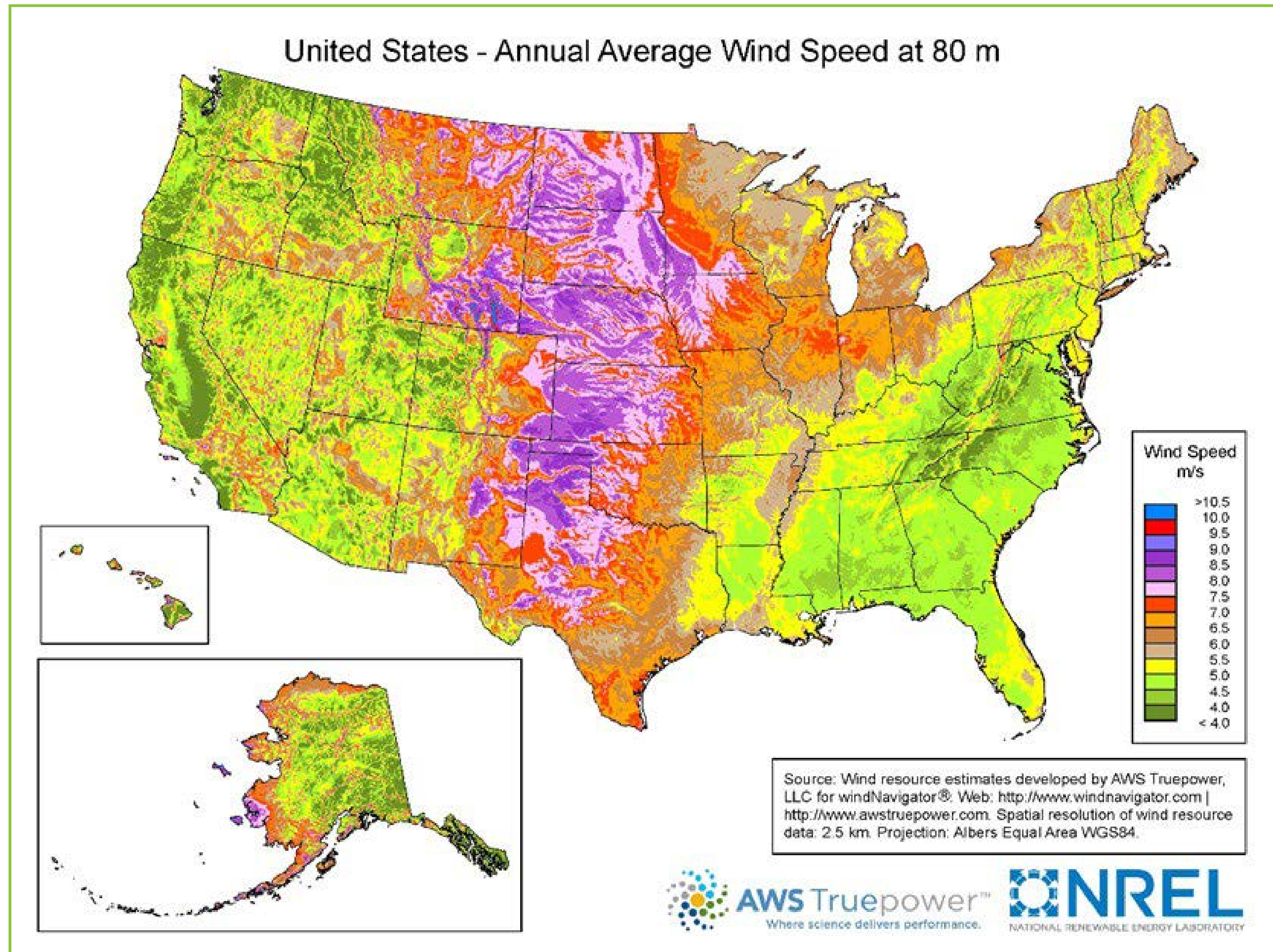
Alliance for Clean Energy New York (ACENY): An advocacy organization that promotes renewable energy, including wind, and supports policies for clean energy development in the state

Maryland Energy Administration (MEA): The MEA offers incentives for residential and community scale wind turbines. In addition, MEA has compiled a number of useful technical resources that will help you understand the basics of wind energy and how to get involved.

West Virginia Office of Energy: The West Virginia Office of Energy is responsible for the formulation and implementation of fossil, renewable and energy efficiency initiatives designed to advance energy resource development opportunities and provide energy services to businesses, communities and homeowners in West Virginia.

U.S. Department of Energy (DOE) - Wind Energy Technologies Office: Offers comprehensive information on wind energy research, technologies, and policy

United States – Annual Average Wind Speed at 80 m





Links

<https://www.gevernova.com>

<https://www.vestas.com/en>

<https://www.siemensgamesa.com/global/en/home.html>

<https://www.nordex-online.com/en/>

<https://www.edpr.com/en>

<https://invenergy.com>

<https://www.nexteraenergyresources.com>

<https://www.uswindenergy.org>

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<https://windenergyfoundation.org>

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<https://www.pawindandsolar.com>

<https://www.ohiowind.org>

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<https://energy.maryland.gov/pages/info/renewable/windprograms.aspx>

<https://www.energywv.org>

<https://www.energy.gov/eere/wind/wind-energy-technologies-office>



Energy & Manufacturing in Appalachia Program

This energy overview research and report was created under the Energy & Manufacturing in Appalachia (EMA) program made possible with grant funding from the Appalachian Regional Commission. EMA provides technical assistance and business support to small and medium manufacturers and enterprises seeking to expand business, production and jobs in the energy supply chains. Energy is a big expense for manufacturing companies. EMA helps companies save money with energy efficiency and emissions reductions.

The EMA program supports Appalachia in 156 counties of Maryland, New York, Ohio, Pennsylvania, and West Virginia. This program was established to help small and medium manufacturers be a part of this Energy Economy. This program is managed by Manufacturing Extension Partnership (MEP) organizations from five Appalachian states. The activities and intended outcomes of EMA align with the National Institute of Standards and Technology (NIST) MEP and its mission to enhance the productivity and technological performance of U.S. manufacturing.

Learn more about the Energy & Manufacturing in Appalachia program by visiting: <https://www.wemakeithere.org/energy/> and join the [EMA LinkedIn group](#).

Contact EMA Program Manager, Tom Reed, directly at Tom@WeMakeItHere.org and (412) 918-4269 with any questions or assistance.