A photograph of a wind farm at sunset. The sky transitions from a deep blue at the top to a bright orange and yellow near the horizon. Several wind turbines are silhouetted against the sky. One large turbine is in the foreground on the right, with its three blades blurred from motion. Three smaller turbines are visible in the background to the left and right. The overall mood is serene and clean.

Careers in wind energy

You see them with growing frequency in some parts of the country: wind turbines, their large blades rotating through the air, far overhead. As a common form of renewable energy, wind power is generating more than just electricity. It is increasingly generating jobs for workers in many different occupations.

The wind energy industry has experienced rapid growth in the past decade. According to the American Wind Energy Association, in 2000, installed wind energy capacity in the United States was less than 3,000 megawatts. It is now more than 35,000 megawatts, enough electricity to power almost 10 million homes.

According to the association, about 85,000 Americans currently work in the wind power industry and related fields. Many workers are employed on wind farms: areas where groups of wind turbines produce electricity from wind power. Wind farms are frequently located in the midwestern, western, and northeastern regions of the United States. Texas, Iowa, and California are the leading States in wind generating capacity.

But many other States are in the process of substantially increasing their wind-generating capacity, and there are wind energy jobs nationwide. Much wind turbine manufacturing is located in traditional manufacturing areas in the Great Lakes and Midwest. Even the Southeast—an area that does not have sufficient wind for generating power—has plants that manufacture wind turbines and components.

This article provides information on some of the career opportunities in wind power. The first section provides an overview of the wind energy industry and the work that goes into building a wind farm. The second section describes selected professional, construction, production, and transportation occupations in the wind energy industry. The third section gives information on typical education and training backgrounds for

workers in these occupations. A final section contains sources for additional research.

Building a wind farm

Developing a wind farm is a challenging process and usually takes several years from inception to construction. This section describes that process, from site selection to operation, and the equipment used in building wind farms.

Site selection and preparation

The wind farm development process begins with the selection of an appropriate site. Engineers and scientists evaluate sites based on several factors, including wind speed and variability, availability of land, the ability of the ground to support the weight of turbines, and environmental concerns.

Project development also has many legal and financial components, such as contract development and financing. Lawyers and permitting specialists are necessary to deal with local, State, and Federal regulations. Land purchasing agents are required to purchase or lease the land.

Because of the size, cost, and complexity of turbines and the difficulty in selecting a site, turbine manufacturing usually runs concurrently with site development. So, developers order turbines during the project development phase.



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Turbines

Wind turbines consist of three major components—the blades, tower, and nacelle—each of which must be designed and produced separately. Modern turbine blades are made of fiberglass and, in onshore models, are frequently more than 100 feet long. Towers are made of several steel segments placed atop one another and can be up to 300 feet tall. The nacelle is the brain of the wind turbine. It is a box resting atop the tower and contains the turbine's controls, gears, generator, and other mechanical components.

The nacelle also contains many highly sophisticated electronic components that allow the turbine to monitor changes in wind speed and direction. To safely and efficiently harness power from the wind, these components direct the wind turbine to turn on and off or change direction automatically.

The blades, tower, and nacelle may be manufactured by a single company or by several working together. But even companies that assemble all their own turbine pieces buy components from third-party suppliers. Smaller companies that make specialized parts, such as blade epoxies and gears, are an important part of the wind industry.

After turbine parts have been manufactured, they need to be delivered to the worksite. Many wind farms are located in remote locations far from turbine manufacturers. Because of the extremely large size of these components, specially designed trucks and railcars are necessary to transport them to worksites. Construction crews build access roads to accommodate these unwieldy vehicles and the valuable components they carry.

When turbine parts are onsite, erection can begin. Under the supervision of more experienced wind-industry workers, local construction firms help build the foundations, made of reinforced concrete, that support the turbines. Skilled crane operators stack the tower segments atop one another before adding the nacelle and blades to the top of the turbine. Electricians build the plant's electricity distribution system and connect the turbines to the power grid.



Wind techs diagnose and solve turbine problems.

Wind farm operation

Once operational, wind turbines can run with little need for human oversight. Energy companies do, however, employ workers to monitor, either locally or remotely, the energy flows and to inform technicians of any problems. All wind farms employ local workers, but remote monitoring of wind turbines allows for a cost-effective way to ensure that the turbine is generating power most efficiently and can alert technicians to any potential problems.

Wind turbine service technicians, also known as “wind techs,” are responsible for keeping turbines running efficiently. When a problem arises, wind techs must be able to diagnose and fix it quickly, as any time that a turbine spends shut off represents lost revenue for the energy company.

It takes a large number of people to build and maintain a turbine, from machinists in factories to technicians working on wind farms every day. Each of these workers along the wind energy supply chain contributes to making wind a viable source of energy in the United States.

Working with wind

This section contains brief descriptions of some selected occupations in the wind energy industry. The occupations are grouped into four different categories—professional, construction, production, and transportation—according to the tasks that workers in each perform.

The U.S. Bureau of Labor Statistics (BLS) does not currently publish employment or wage data specific to the wind energy industry. However, the table below shows the median annual wage (across all industries) of the occupations described in this section.

Wages for selected wind-related occupations, May 2009

Occupation	Median annual wage, May 2009
Professional occupations	
Aerospace engineer	\$94,780
Electrical engineer	83,110
Civil engineer	76,590
Atmospheric scientist	84,710
Wildlife biologist	56,500
Logistician	67,960
Construction occupations	
Construction laborer	29,150
Electrician	47,180
Construction equipment operator	39,770
Production occupations	
Machinist	37,650
Computer-controlled machine tool operator	34,460
Assembler	26,820
Quality control inspector	32,330
Transportation occupations	
Truck driver, heavy and tractor-trailer	37,730
Crane and tower operator	44,140

Professional occupations

Workers in these occupations perform a variety of skilled functions, such as computing, teaching, and designing. Professional occupations in the wind energy industry include engineers, scientists, and logisticians.

Aerospace engineers. These workers design, test, and supervise the manufacture of turbine blades and rotors, and conduct aerodynamics assessments. They are frequently involved in site selection and work closely with meteorologists to determine the optimal configuration of turbines at a wind farm site.

Electrical engineers. Electrical engineers design, develop, test, and supervise the manufacture of turbines' electrical components. The components include electric motors, machinery controls, lighting and wiring, generators, communications systems, and electricity transmission systems.

Civil engineers. These engineers design and supervise the construction of many parts of wind farms, including roads, support buildings, and other structures such as the tower and foundation portions of the wind turbine. Because of the scale of wind turbines, these engineers must deal with some unique problems, such as designing roads that can withstand very heavy loads and accommodate trailers that are up to 100 feet long.

With many wind farms located in the Midwest and western States, civil engineers must consider potential hazards, ranging from extreme winds and cold temperatures to earthquakes. Civil engineers in wind power typically specialize in structural, transportation, construction, or geotechnical engineering.

Atmospheric scientists. Often referred to as meteorologists, atmospheric scientists monitor the atmosphere around a potential project to ensure that there is adequate wind to produce electricity. They also assess whether the wind or other weather conditions may be too extreme for viable wind development.

Atmospheric scientists take wind measurements over a period of months or years and use computer models to judge whether the wind is adequate for turbine operation. In addition, these scientists help decide the

Atmospheric scientists use charts and weather models to determine the best sites for wind farms.



placement of turbines at the site to ensure that the greatest possible amount of energy is obtained from the wind.

Wildlife biologists. These workers evaluate the wind farm's effect on local animal life. Although wind turbines do not take up a lot of space, construction can be disruptive to the natural environment. Operational turbines also pose a serious threat to local and migrating bird and bat populations. Biologists must make sure that the impact on these populations is minimal.

Wildlife biologists spend a great deal of their time outdoors at a site, cataloging the surrounding wildlife and making recommendations on how to avoid interfering with local ecosystems. They also write reports on environmental impact.

Logisticians. Logisticians are responsible for keeping transportation as efficient as possible. Because wind farm projects are expensive and run on tight schedules, time spent waiting for delayed turbine components costs money. Logisticians work extensively with both manufacturers and construction teams

to develop a schedule for timely delivery of turbine components.

State-to-State differences in heavy trucking regulations present unique challenges to logisticians. Some States require police escorts within their borders, and others do not even allow trucks over a certain tonnage to travel on their roads. Logisticians must consider these varied regulations when planning routes. They must also take mechanical considerations, such as a truck's turning radius, into account when mapping routes.

Construction occupations

Workers in these occupations build and repair roads, buildings, and other structures. Construction occupations in the wind energy industry include laborers, electricians, and equipment operators.

Construction laborers. Construction laborers often work on wind farms as contractors and are responsible for preparing the site and building the surrounding infrastructure. Their work includes clearing trees and debris from the wind farm, cleaning machines, and

helping prepare the ground that will support the turbines.

Construction workers employed by companies that specialize in developing wind farms sometimes have supervisory roles. They might work under the project manager to direct local contractors and confirm that all onsite work is performed safely and correctly. Construction workers might also be trained as wind turbine service technicians.

Electricians. These workers help get the energy from the turbine's generator to the power grid on the ground. They wire the turbine to connect its electrical system to the power grid. When installing wiring, electricians use hand tools such as conduit benders, screwdrivers, pliers, knives, hacksaws, and wire strippers, as well as power tools such as drills and saws.

Construction equipment operators. With the help of construction laborers, construction equipment operators build accessible roads to the construction site. Their efforts ensure that the wind turbine components arrive without damage or delay. They use bulldozers, road graders, and other equipment to set up the construction site.

Production occupations

By operating machines and other equipment, workers in this group assemble goods and distribute energy. Production occupations in the wind energy industry include machinists, machine tool operators, assemblers, and inspectors.

Machinists. Machinists use many different tools to produce precision metal and plastic pieces in numbers too small to be manufactured with automated machinery. They use their technical knowledge to review blueprints and ensure that pieces are machined to precise specifications.

Machinists may also finish parts that were made by automated machinery.

Before beginning to cut, machinists must plan how to position and feed the materials into the machine. And during the machining process, machinists must constantly monitor the feed rate and speed of the machine while staying alert for any potential problems.

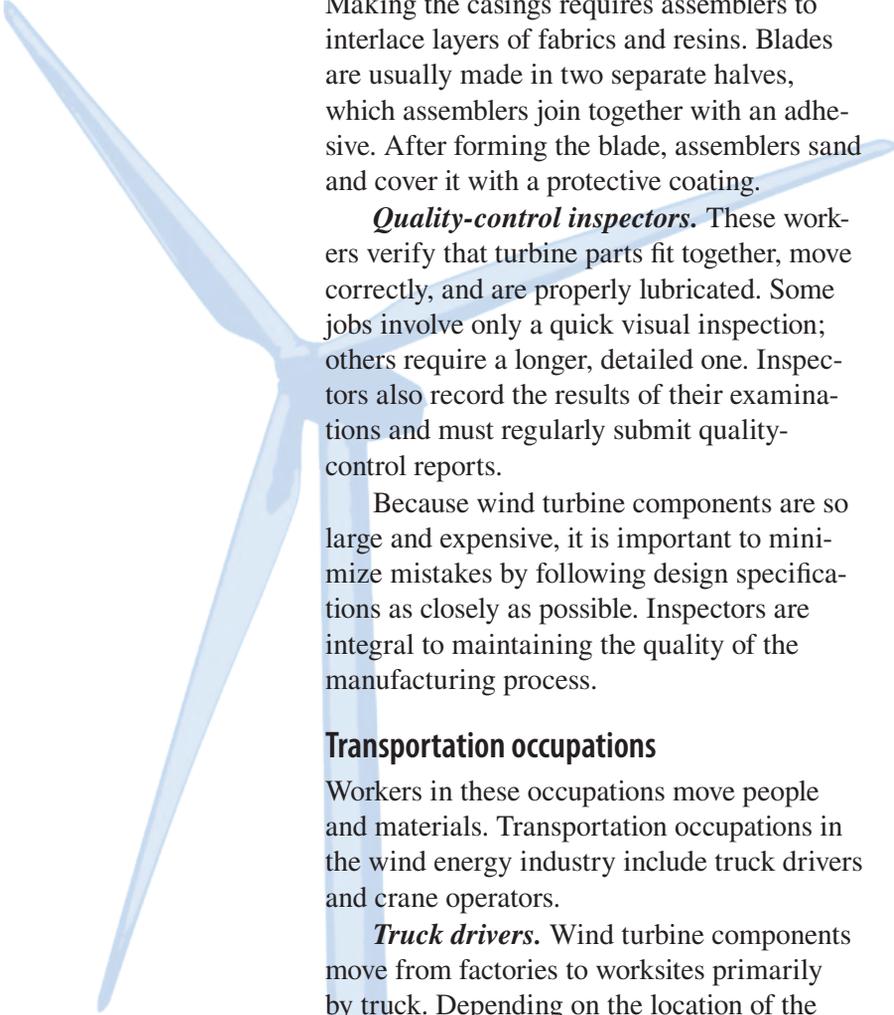
Computer-controlled machine tool operators. These workers run computer-controlled machines, which use the machine tool to form and shape turbine components. The machines use the same techniques as many other mechanical manufacturing machines but are controlled by a central computer, instead of a human operator or electric switchboard. Some highly trained workers also program the machines to cut new pieces according to designers' schematics.

These operators usually use machines to mass-produce components that require cutting with a high level of precision. In the wind-turbine supply chain, they manufacture many of the finely cut pieces, including those which are part of the generator or drive train.

Assemblers. Assemblers put the turbine components together. Despite increased



Wind turbine components are manufactured to design specifications by machinists, machine tool operators, and assemblers.



automation, many parts still have to be put together and fastened by hand. After determining how parts should connect, assemblers use hand or power tools to trim, cut, align, and make other adjustments. When the parts are properly aligned, assemblers connect them with bolts and screws or by welding or soldering pieces together.

Assemblers work extensively in the production of all turbine components. Manufacturing blades, for example, is labor intensive. Making the casings requires assemblers to interlace layers of fabrics and resins. Blades are usually made in two separate halves, which assemblers join together with an adhesive. After forming the blade, assemblers sand and cover it with a protective coating.

Quality-control inspectors. These workers verify that turbine parts fit together, move correctly, and are properly lubricated. Some jobs involve only a quick visual inspection; others require a longer, detailed one. Inspectors also record the results of their examinations and must regularly submit quality-control reports.

Because wind turbine components are so large and expensive, it is important to minimize mistakes by following design specifications as closely as possible. Inspectors are integral to maintaining the quality of the manufacturing process.

Transportation occupations

Workers in these occupations move people and materials. Transportation occupations in the wind energy industry include truck drivers and crane operators.

Truck drivers. Wind turbine components move from factories to worksites primarily by truck. Depending on the location of the manufacturer and the worksite, rail and water transportation are also sometimes used. But because wind farms are frequently built on remote inland sites, truck drivers are usually hired to transport components.

Each blade, tower segment, and nacelle is hauled individually in specially fitted vehicles. Highly trained drivers are responsible for handling their large vehicles expertly, regardless

of road conditions, to deliver turbine components safely and on time. Truck drivers are expected to regularly update managers, informing them of any schedule changes or delays.

Crane operators. Because wind turbine components are so large, building them on a wind farm requires the use of heavy equipment. As a result, crane operators are integral to the construction job, too. For example, these workers operate cranes to lift the pieces of the turbine off the trucks, stack the tower segments, and lift the blades to the hub.

Education and training for wind workers

Because workers from so many occupations are employed in the wind energy industry, they have diverse education and training backgrounds. Careers in wind energy are available for people at many different education, training, and skill levels.

Workers in professional occupations, such as engineers, scientists, and logisticians, usually have at least a bachelor's degree. Some jobs, however, require additional education, such as a master's or doctoral degree. Post-graduate education in wind-specific issues is also usually necessary for professional workers who want to enter the wind energy industry.

Many construction and production jobs have no specific education or training requirements, although some workers receive more formal training through apprenticeships. Many workers learn skills on the job and by assisting more experienced workers. Some construction workers, including construction equipment operators and electricians, require more training and might need certification.

Truck drivers transporting turbine components need a commercial driver's license. Training for this license is offered by many private and public vocational-technical schools. Employers also have training programs for new drivers who have earned their commercial driver's license. Because of the

difficulty in driving the specialized vehicles that transport turbine components, drivers must be highly skilled. Drivers may operate larger vehicles as they gain experience.

For more information

For information about careers in wind energy, visit your local library or One-Stop Career Center. You can locate a nearby career center online at www.servicelocator.org.

In addition to workers in the occupations discussed in this article, many others are involved in the wind energy industry.

Like most businesses, companies in wind energy employ workers in administrative positions, including secretaries and receptionists, human resources specialists, accountants and auditors, lawyers, and managers. People in these jobs ensure that companies involved in the wind energy industry run smoothly by taking care of personnel, budget, and legal issues.

For facilities to be properly maintained and secured, wind energy firms rely on janitors, maintenance workers, and security guards. Janitors and custodians are responsible for the cleaning and upkeep of facilities, and maintenance workers make sure that machinery are kept in safe operating condition

and repair broken equipment. Security guards ensure that the facilities are free of unauthorized people and that problems are reported as soon as they occur.

Information about these and hundreds of other occupations can be found in the *Occupational Outlook Handbook*. It is available in print at many public libraries and career centers. The *Handbook* is also online at www.bls.gov/ooh.

Excluded from the occupations discussed in detail in this article is wind turbine service technician. This occupation, which is critical to the wind energy industry, is described in the fall 2010 *Occupational Outlook Quarterly* article "You're a *what?* Wind turbine service technician." This article is available online at www.bls.gov/ooq/2010/fall/yawhat.htm.

Additionally, more detailed information on the wind energy industry is available in a recent BLS report, which can be read online at www.bls.gov/green/wind_energy.

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