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Careers in Wind Energy

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Wind power has been used for centuries, but is a relatively new source of electricity generation. Visually identifiable by its characteristic turbines, wind power has been used on a utility scale for only a few decades. Wind-generating capacity in the United States grew 39 percent per year from 2004 to 2009, and is expected to grow more rapidly as demand for renewable energy increases.[1] As the wind energy industry continues to grow, it will provide many opportunities for workers in search of new careers. These careers extend beyond the wind farm: it also takes the efforts of workers in factories and offices to build and operate a turbine.

The wind energy industry has experienced rapid growth in the past decade. According to the American Wind Energy Association (AWEA), in 2000, installed wind energy capacity in the United States was under 3,000 megawatts. It is now over 35,000 megawatts, enough electricity to power approximately 9.7 million homes.[2] And this growth is accelerating. In 2009, 10,010 megawatts of new wind energy capacity was installed, more than in any previous year. As wind energy continues to grow in popularity, the development of American wind farms is expected to increase. Of course, the pace of wind energy development is influenced by current economic conditions.

Despite this growth, wind power is only a tiny segment of the national energy market. In 2009, wind energy made up 1.8 percent of U.S. power generation, an increase from 1.3 percent in 2008. However,

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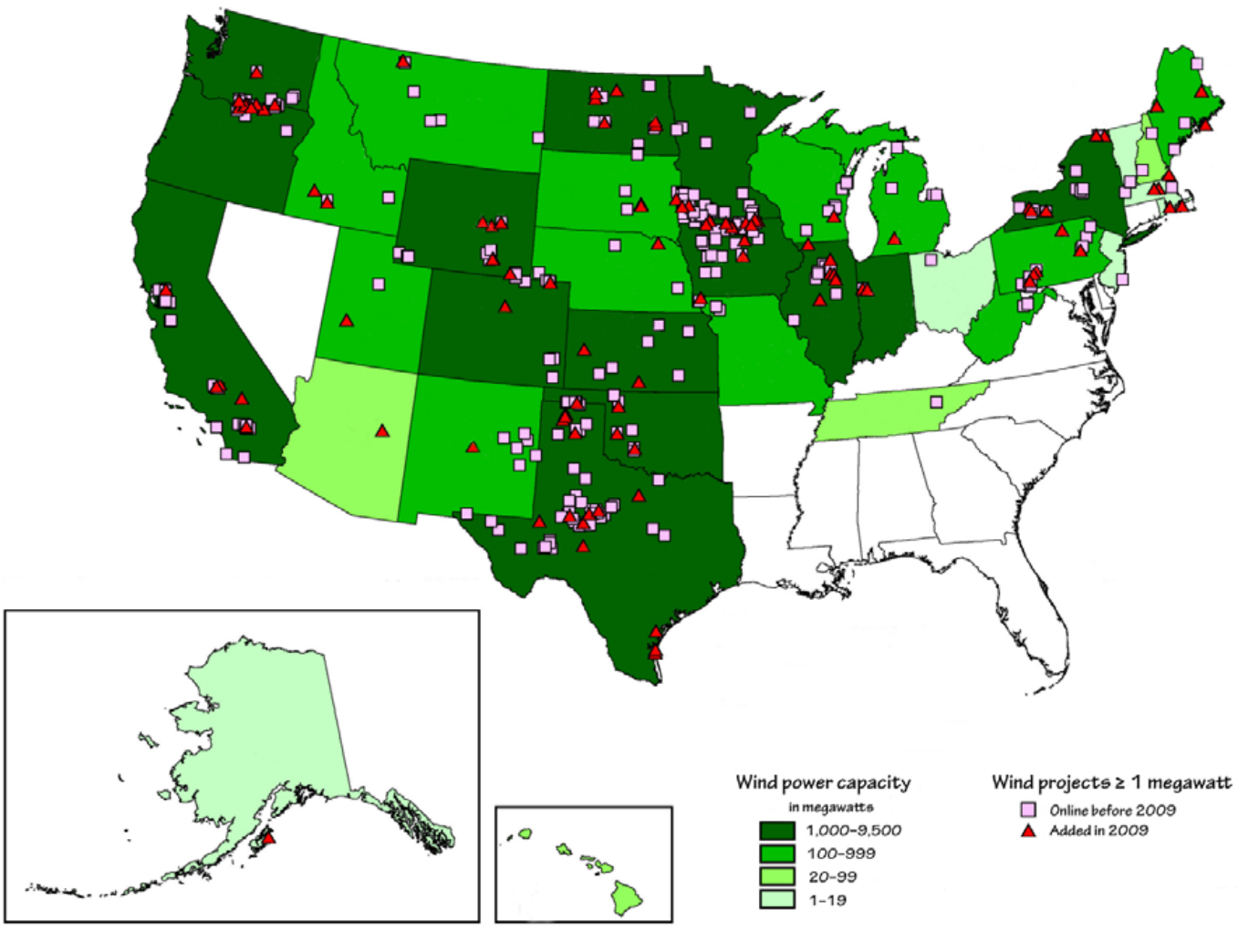
Map 1. Wind farms in the United States, as of year-end 2009

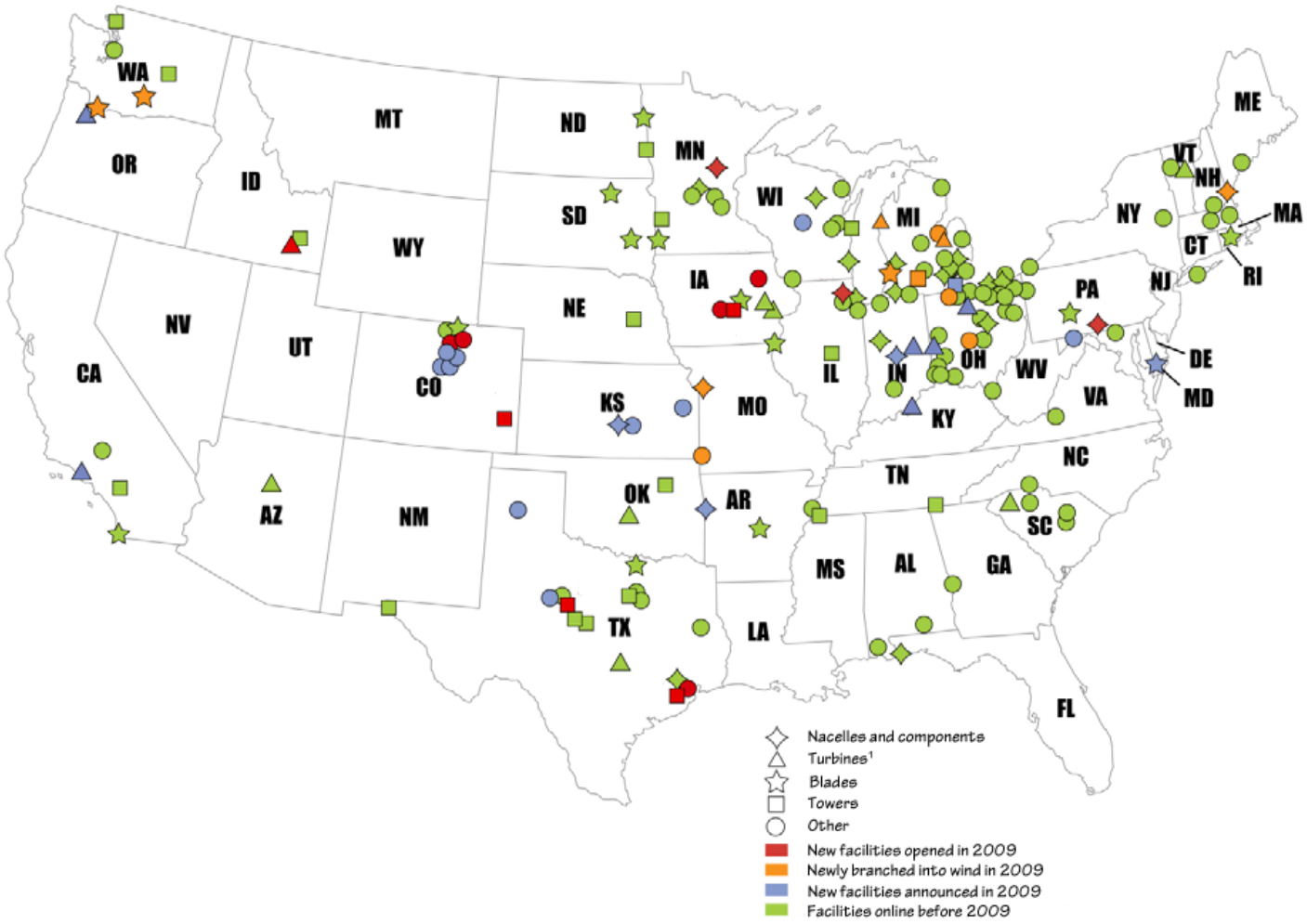


SOURCE: National Renewable Energy Lab, Department of Energy

wind power accounts for about 50 percent of renewable energy, which includes wind, solar, hydroelectric, and geothermal power, as well as energy from biomass and wood or wood-derived products.[3] Some States rely significantly more on wind power to fill their energy needs. For example, in 2009, 19.7 percent of Iowa's electricity was produced by wind power.[4] Growth in wind power is expected to continue. According to a report by the Department of Energy, it may be feasible for wind power to provide 20 percent of U.S. electricity needs by the year 2030.[5]

According to AWEA, an estimated 85,000 Americans are currently employed in the wind power industry and related fields. Many workers are found on wind farms, which are frequently located in the Midwest, Southwest, and Northeast regions of the United States. Texas, Iowa, and California are the leading States in wind power generating capacity, but many other States—including Illinois, Indiana, Oregon, and Washington—are in the process of substantially increasing their wind-generating capacity. (See map 1.)

Map 2. Facilities currently producing components of turbines, as of year-end 2009



SOURCE: National Renewable Energy Lab, Department of Energy

1. Facilities designed as "turbines" typically include turbine assembly or turbine component manufacturing, such as the manufacturing of towers, nacelles, and blades.

Although some States are better known for wind power than others, there are wind energy jobs in almost every State in the country. Much wind turbine manufacturing is located in traditional manufacturing areas in the Great Lakes and Midwest, as well as in the southeastern United States, where there is not sufficient wind for substantial power generation. (See map 2.)

This report provides information on various career opportunities in wind power. The first section provides an overview of the wind energy industry and the work that goes into creating and running a wind farm. The remainder of the report details occupations integral to the wind energy industry. Each occupational profile includes information on job duties, education and training requirements, and wages.

The primary focus of this report is utility-scale wind generation. Wind power generation on a smaller scale, known as "small wind," is used by some individual residences and business establishments. These smaller wind turbines generate electricity that is used to power individual buildings or building complexes.

Diagram 1. The wind energy supply chain

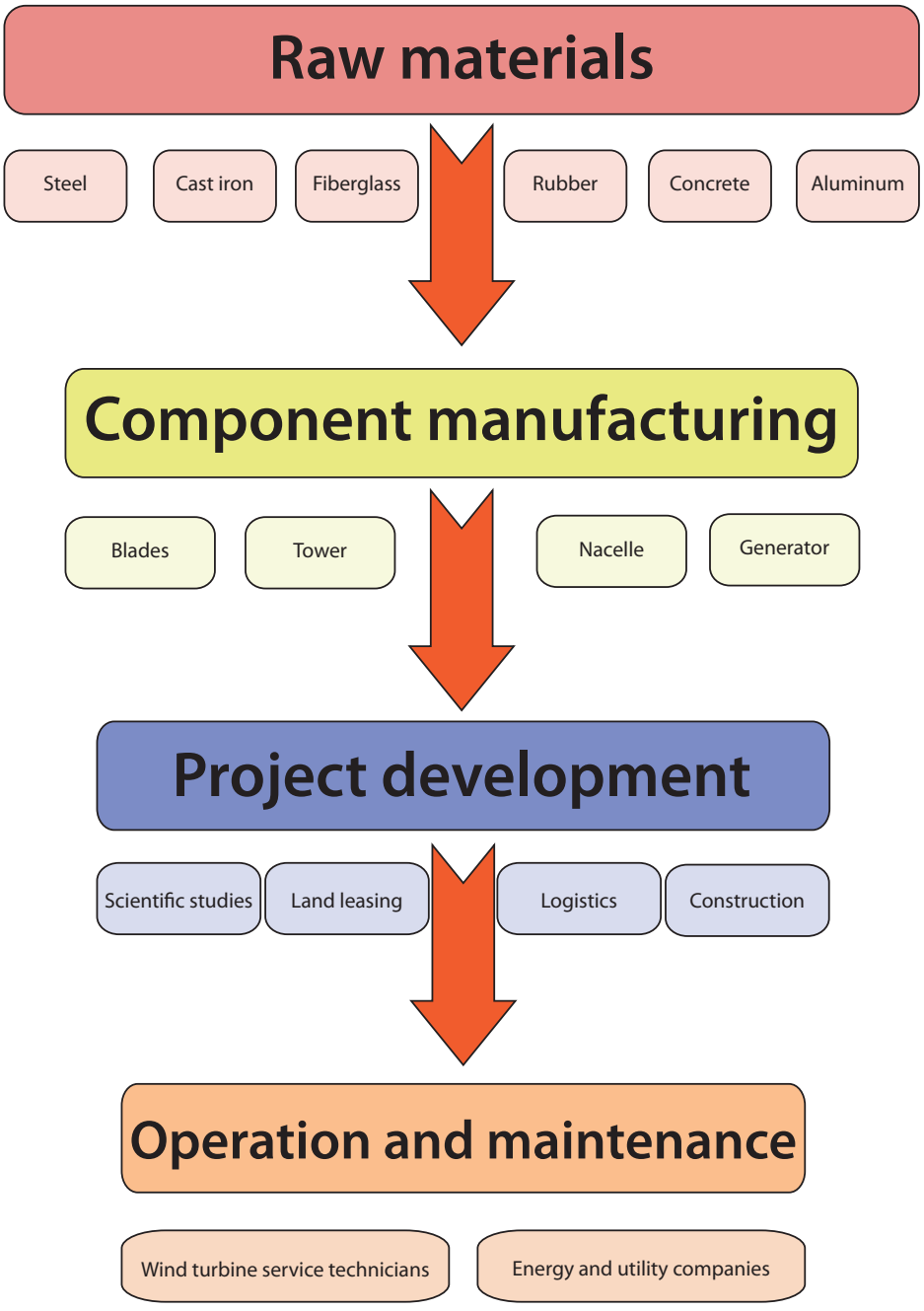
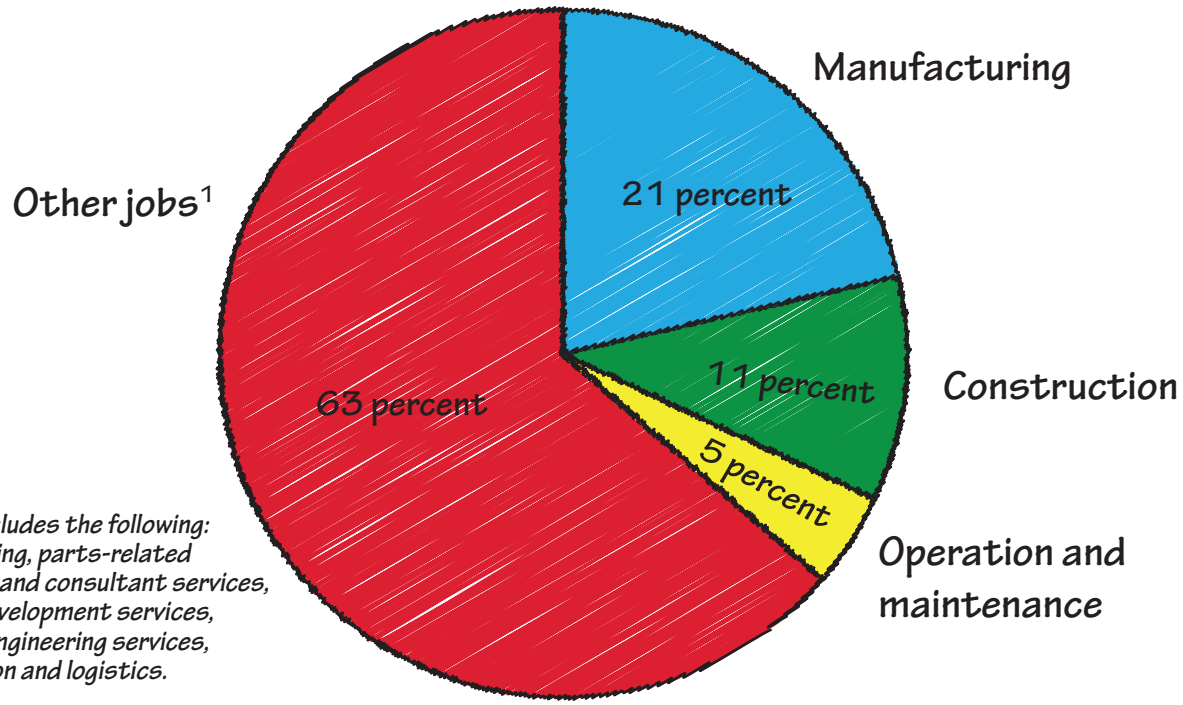


Chart 1. Jobs in wind power, 2009



1. "Other jobs" includes the following: some manufacturing, parts-related services, financial and consultant services, developers and development services, contracting and engineering services, and transportation and logistics.

SOURCE: American Wind Energy Association

Overview of a Wind-Farm Project

The process of getting energy from the wind into the home or business is complex and involves many players. (See diagram 1.) A modern wind turbine consists of an estimated 8,000 parts and can be up to 300 feet high.6 Turbines must be designed, built, transported, and erected before they can start producing energy. This process can be split into three major phases: manufacturing, project development, and operation and maintenance. Each of these phases will be discussed separately, but in a successful project, these phases overlap and there is substantial communication among players in all three phases.

Currently, most of the jobs in wind power are in the manufacturing sector, followed by construction, and operation and maintenance. However, as new wind farms are brought online, existing ones are upgraded, and manufacturers are able to take advantage of returns to scale, the other sectors also are expected to experience rapid growth. Chart 1 shows the distribution of jobs in the wind power industry in 2010.

Manufacturing Phase

Wind turbines are large, complex pieces of machinery designed and built by companies known as original equipment manufacturers (OEMs). Some OEMs are large multinational corporations for which wind turbine manufacturing is only a small piece of their global business. Other companies do business solely in the wind

power industry. These companies rely on many smaller establishments to construct the individual components and systems that make up a wind turbine.

Many of the OEMs producing wind turbines are based overseas, and many domestically based OEMs manufacture major turbine components outside the United States. However, many foreign OEMs are localizing production in the United States in order to take advantage of the growing market, reduce transportation costs, minimize the risks associated with currency fluctuations, ease logistical challenges associated with exporting large turbines and components, and avoid import duties.7

OEMs are the major players in the wind industry. These companies conduct research and development that leads to innovations in wind turbines. New turbines need to be rigorously designed by teams of engineers. Because of the large size of wind turbines, testing the equipment presents many challenges and the design phase is extremely important. OEMs must incorporate new technologies and constantly innovate to stay competitive. After designing a wind turbine, OEMs have to take the turbine schematics off the page and turn them into functioning turbines.

Wind turbines consist of three major components—the blades, tower, and nacelle—each of which has to 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 up of several steel segments placed atop one another. The brain of the wind turbine is the nacelle, a rectangular box resting atop the tower and containing the turbine's 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. These components can direct the wind turbine to turn on and off or change direction automatically in order to safely and efficiently harness power from the wind. (See diagram 2.)

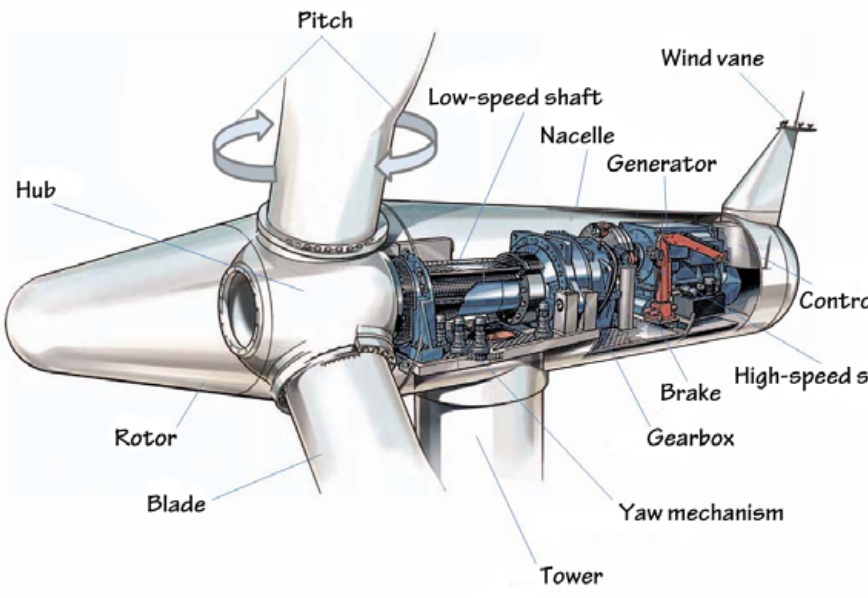
The business and supply models of OEMs vary. The blades, tower, and nacelle may be manufactured by the OEM itself or contracted out to suppliers to be built to the OEM's specifications. Even OEMs that assemble their own turbine pieces have to buy some components from third-party suppliers. The wind industry supports many smaller companies that make specialized parts, such as blade epoxies and gears for the OEMs.

Whether manufactured by the OEM or a supplier, the blades, towers, and nacelles are all built separately at different factories, many of which are located around traditionally industrial areas in the Midwest and around the Great Lakes. The growth of the wind industry will provide new opportunities for many American workers. As turbine manufacturers import fewer components, more domestic manufacturing jobs could be created.

Project Development Phase

Wind farm development is a challenging process that usually takes several years from inception to construction. The process begins with the selection of an appropriate site. Site selection involves a number of factors, including wind speed and variability, availability of land, the ability of the ground to support the weight—often in excess of 1000 tons—of turbine structures, the feasibility of transporting large turbine components to the site,

Diagram 2. The major components of a wind turbine



SOURCE: Center on Globalization, Governance, and Competitiveness, Duke University

and environmental concerns—such as local bird and bat populations. Project development also has many legal and financial components such as contract development and financing. All of this work must be done before the first shovel can break ground.

A key element in the project development phase is community relations. Wind turbines are large, visually imposing structures that can produce significant amounts of noise. Projects must gain the support of local communities, and developers must work with the local community to ensure that everyone realizes the benefits of wind projects.

Because of the complexity of developing a wind farm, many occupations are involved in the process. Lawyers and permitting specialists are necessary to deal with local, State, and Federal regulations. Land purchasing agents are required in order to purchase or lease the land. And engineers and scientists must ensure that the site is adequate for a wind farm.

Once a site is determined to be suitable for development, the necessary permits have been obtained, and financing has been secured, the turbines are ordered and the manufacturing process begins. Because of the size, cost, and complexity of turbines and the difficulty in selecting a site, turbine manufacturing must run concurrently with site development. Before the turbines can arrive, the site must be cleared and roads must be in place. The foundations, which consist of concrete and steel, also must be complete before the installation of the turbines.

Another challenge facing developers is the transportation of the turbine components 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. Some development companies handle their own transportation and logistics issues, whereas others hire trucking companies that specialize in hauling large equipment.

After the land is purchased or leased, the foundations have been built, and the turbine parts have arrived onsite, the turbines are ready to be erected. Many development and construction companies use both their own specialized construction workers and local contractors. Under the supervision of more experienced wind-industry workers, local construction firms help build access roads and the foundations, made of reinforced concrete, that rest under the turbines. Skilled crane operators stack the tower segments atop one another before adding the nacelle and blades to the top of the turbine.

When planning the wind farm, the owner will enter into a contract, known as a power purchase agreement, with the utility company. Each wind turbine functions as its own power plant, and the energy it produces is gathered into substations to be converted into usable electricity. Electricians are necessary to build the plant's electricity distribution system and connect the turbines to the power grid.

Operation and Maintenance Phase

Wind turbines can run with little need for human supervision. Energy companies employ monitors, either locally or remotely, to observe energy flows and inform technicians of any problems. All wind farms employ local workers, but remote monitoring of wind turbines can allow for a cost-effective way to ensure that the turbine is generating power most efficiently and that local technicians are alerted to any potential problems.

Wind turbine service technicians, also known as "wind techs," are responsible for keeping the turbines running efficiently. These technicians climb up and down the ladders housed within the tower to reach the nacelle and blades. On the top of turbines they perform preventative maintenance and do routine checks. When a problem arises wind techs must be able to diagnose and fix it quickly, as any time the turbine spends shut off is money lost to the energy company.

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

Occupations in Wind Power

For the purposes of this report, occupations in wind power are separated into three phases: manufacturing, project development, and operation and maintenance. However, occupations are not always limited to one phase. For example, engineers are used in both manufacturing and project development, but in this report they are discussed in the manufacturing section. Wind turbine service technicians work in all three phases, but are listed here under operation and maintenance.

Most of the occupations detailed in this section are not specific to the wind power industry. Although many

of these jobs require special skills unique to wind power, in most cases, skills can be acquired in other industries. For most positions, the wind companies hire people with experience in other industries and give them wind-specific training.

The primary exception to this trend is the wind turbine service technician. Currently, a large portion of these technicians learn on the job or through apprenticeship programs. However, as more vocational training programs are developed and training is standardized, technicians will be expected to have formal training and a certificate or degree. More information will be provided later in this report.

Occupations Relevant to the Manufacturing Phase

Research and development is a key aspect of any industry, but because wind power is a relatively new industry in the United States, it is vital for manufacturers to invest in new technologies and processes. There are hundreds of companies involved in manufacturing turbines and turbine components, and because of the competition in the industry, each firm must find innovative ways to make turbines more powerful, efficient, and reliable—without significantly increasing costs.

Key careers in wind turbine research and development are those of scientists, engineers, and engineering technicians. Scientists involved in R&D include atmospheric scientists and materials scientists, who must design components that can efficiently generate the most power and withstand environmental stresses. (Science occupations will be discussed in the project development section of this report.)

The three major pieces of a wind turbine—the blades, the tower and the nacelle—are all difficult to produce. Contained within the nacelle are the turbine's drive train and generator, and other mechanical and electrical components. All of these pieces must be manufactured to meet design specifications. Workers in many different occupations, including machinists, computer-controlled machine tool operators, assemblers, welders, quality-control inspectors, and industrial production managers, are involved in manufacturing the turbine components.

Research and Development Jobs

Engineers in the wind power industry are involved in the design and development of wind turbines. In addition, they also work in testing, production, and maintenance. Engineers may also supervise production in factories, test manufactured products to maintain quality, and troubleshoot design or component problems. They also estimate the time and cost required to complete projects and look for ways to make production processes more efficient. Supervisory engineers are responsible for major components or entire projects and typically lead a team of engineers and technicians.

Engineers use computers extensively to produce and analyze designs, generate specifications for parts, monitor product quality, and simulate and test how a turbine or component operates. Because of the complexity of wind turbines, several types of engineers are employed by the industry. The following is a partial list of the types of engineers employed in the wind power industry: aerospace engineers, civil engineers, computer engineers, electrical engineers, environmental engineers, health and safety engineers, industrial engineers, materials engineers, and mechanical engineers.

Job duties

Engineers in the wind power industry work in offices, laboratories, and industrial plants. Some may spend time at working wind farms and those under development. Many are expected to travel frequently to oversee manufacturing processes or turbine installation, and travel abroad is often required since many of the largest turbine manufacturers are based overseas. The nature of engineers' work depends largely on their specialties.

Aerospace engineers design, test, and supervise the manufacture of turbine blades and rotors, and conduct aerodynamics assessments. They are frequently involved

in site selection, working closely with meteorologists to determine the optimal configuration of turbines at a wind farm site.

Civil 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 atypical problems, such as designing roads that can withstand very heavy loads as well as trailers that are up to 100 feet long. Since many wind farms are located in the Midwest and western States, they have to consider potential hazards ranging from extreme winds and cold temperatures to earthquakes. Civil engineers in wind power typically specialize in structural, transportation, construction, and geotechnical engineering.

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

Electronics engineers are responsible for systems that use electricity to control turbine systems or signal processes. Whereas electrical engineers work primarily with power generation and distribution, electronics engineers deal with the complex electronic systems used to operate the turbine.

Environmental engineers deal with the potential environmental impacts of wind turbines. Although wind power is one of the most environmentally friendly sources of electricity, there are still some environmental concerns that engineers must consider. These include noise, visual impact, the impact on local species, interference with radar and telecommunications, and electric and magnetic fields caused by electricity-generating equipment.

Health and safety engineers identify and measure potential hazards of wind turbines, and implement systems that ensure safe manufacture and operation. They usually recommend appropriate loss-prevention measures according to the probability of harm or damage.

Industrial engineers determine the most effective ways to use the basic factors of production to make components of wind turbines. They are concerned primarily with increasing productivity and minimizing costs in the manufacture of turbine systems and components. Industrial engineers study product requirements and design manufacturing and information systems to meet those requirements with the help of mathematical models. They also aid in financial planning, cost analysis, and the design of production processes and control systems.

Materials engineers develop, process, and test materials used to construct wind turbines. Wind turbines consist of thousands of parts, and each must be designed to exacting specifications because of the stresses involved in generating wind power. Materials engineers must work with metals, ceramics, plastics, semiconductors, and composites that meet certain mechanical and electrical requirements.

Mechanical engineers work on a variety of machines and other mechanical devices. They research, design, develop, and test tools and mechanical devices. These engineers work on wind turbine components, wind turbine systems, or the machinery that is used to manufacture and test the turbines. Many of these engineers also supervise manufacturing processes.

Engineering technicians assist engineers and scientists, especially in research and development and in the manufacturing process. Some work in quality control, inspections, and data collection. They assist with design by use of computer-aided design and drafting equipment, collect data, and calculate or record results. Engineering technicians are also responsible for operating and maintaining design and test equipment.

Education and training

Engineers typically enter the wind power industry with at least a bachelor's degree in an engineering specialty. However, a significant number of jobs require more education, such as a master's or doctoral degree. In addition, engineers typically are licensed and are expected to complete continuing education to keep current with rapidly changing technology.

Wind turbine manufacturers prefer to hire engineers with 3–5 years of experience in their respective field and knowledge of commonly used systems and processes. Engineers are then given additional training lasting several weeks or months prior to assignment, and then they undergo extensive on-the-job training.

Entry-level engineers may also be hired as interns or junior team members and work under the close supervision of more senior engineers. As they gain experience and knowledge, they are assigned more difficult tasks and given greater independence.

Certifications are usually required, depending on the systems used by a particular manufacturer. Licensure as a professional engineer (PE) is desirable, but is not required for many wind turbine manufacturers. Engineer-

ing technicians typically have an associate's degree or a certificate from a community college or technical school.

Earnings

BLS does not currently publish earnings data specific to the wind power industry, but earnings for engineers in wind power are comparable to earnings for engineers in general. The following tabulation shows annual wages for engineers in selected specialties.

Earnings are dependent on a number of factors, such as experience, education and training, licensure and certifications, the size and type of company, geographic location, and the complexity of the work.

Type of engineers	Median annual wages
Aerospace engineers	$94,780
Civil engineers	76,590
Electrical engineers	83,110
Electronics engineers, except computer	89,310
Environmental engineers	77,040
Health and safety engineers, except mining safety engineers and inspectors	74,080
Industrial engineers	75,110
Materials engineers	83,190
Mechanical engineers	77,020
Engineers, all other	89,560
Engineering technicians, except drafters	50,130

General Manufacturing Jobs

Producing turbine components that match design specifications is the responsibility of manufacturing workers. The wind-energy supply chain requires the skills of many different production occupations, including machinists, computer-controlled machine tool operators, assemblers, welders, quality-control inspectors, and industrial production managers. The job duties, skills, and training backgrounds of these workers are similar to those of manufacturing employees in other industries.

Wind turbine production workers may be employed by either OEMs or third-party suppliers. Many factories manufacturing components for wind turbines are located in the Midwest, sometimes in converted auto plants. Some new production facilities are being built in Colorado and Pennsylvania, States that actively pursue the development of wind power. As more wind energy manufacturers open factories in the United States, new job opportunities will be created.

Job duties

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 the specifications of OEM engineers. 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 keeping an eye out for any potential problems.

Computer-controlled machine tool operators run computer numerically controlled (CNC) machines, which use the machine tool to form and shape turbine components. CNC 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 CNC workers also program the machines to cut new pieces according to designers' schematics.

CNC 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 are responsible for putting the components together into a larger product. Despite increased 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, shim, cut, and make other adjustments to align and fit components. Once the parts are properly aligned, they connect them with bolts and screws or by welding or soldering pieces together.

Assemblers are used extensively in the production of all turbine components. Manufacturing blades, for example, is extremely 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 the blade has been formed, they sand and cover it with a protective coating.

Welders apply heat to metal pieces, melting and fusing them to form a permanent bond. The types of equipment welders use are dependent on the job they are performing and material with which they are working. Some welding is done by manually using a rod and

heat to join metals, whereas other welding is semiautomatic, meaning that a wire-feed welding machine is used to bond materials. In the wind industry, welders work on many diverse components; for example, they weld together cylinders of rolled steel to form turbine tower segments.

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

Because wind turbine components are so large and expensive, it is extremely important that no mistakes be made and that design specifications be followed precisely. Inspectors are integral to maintaining the quality of the manufacturing process.

Industrial production managers plan, direct, and coordinate the work on the factory floor. They may determine which machines will be used, whether new machines need to be purchased, whether overtime or extra shifts are necessary, and how best to improve production processes. Industrial production managers also monitor the production run to make sure that it stays on schedule.

Industrial production managers are also responsible for solving any problems that could jeopardize the quality of their company's components. If the problem relates to the quality of work performed in the plant, the manager may implement better training programs or reorganize the manufacturing process. If the cause is substandard materials or parts from outside suppliers, the industrial production manager may work with the supplier to improve quality.

Education and training

The type of training necessary for these production occupations varies. Many workers are trained on the job and gain expertise with experience. However, some workers in more skilled positions, such as computer-controlled machine tool operators, may be required to attend formal training programs or apprenticeships. A strong mechanical background is necessary to succeed in all of these occupations.

Many industrial production managers have a college degree in business administration, management, industrial technology, or industrial engineering. After they graduate, they usually spend a few months in corporate training, learning company policies and production methods for wind turbine components. Others become industrial production managers by working their way up through the ranks, starting as production workers and then advancing to supervisory positions before being selected for management.

Because of the relative youth of the wind energy industry, it can be difficult to find workers with a background in wind power; many turbine component manufacturers will hire almost any qualified applicants with a related technical background. Experience in the manufacture of large machines can be especially helpful. Workers from other backgrounds can be taught on the job how to apply their manufacturing skills to turbine components.

Earnings

As stated earlier, BLS does not have wage data specific to the wind energy industry. However, the following tabulation shows BLS data for selected production occupations in the engine, turbine, and power transmission equipment manufacturing industry group, which includes wind turbine component manufacturing. The wages listed here should be similar to those earned by workers employed in the wind industry. Of course, wages vary by employer and location.

Occupation	Median annual wages
Machinists	$41,480
Computer-controlled machine tool operators, metal and plastic	34,790
Team assemblers	29,320
Welders, cutters, solderers, and brazers	35,920
Inspectors, testers, sorters, samplers, and weighers	37,500
Industrial production managers	87,120

Occupations Relevant to Project Development

Building a wind farm is a complex process. Site selection alone requires years of research and planning. And the proposed site must meet several criteria, such as developable land, adequate wind, suitable terrain, and public acceptance. In addition, wind turbines must be deemed safe for local wildlife, particularly birds, and be sited away from populated areas because of noise and safety concerns. Scientists, land acquisition specialists, asset managers, lawyers, financers, and engineers are

needed to ensure the site is suitable for wind farm development.

After the site is selected and construction begins, workers are needed to install the turbines and support structures. This requires the work of many skilled people, including construction workers, crane operators, wind turbine service technicians, and truck drivers.

Land Acquisition, Asset Management, and Logistics

Land acquisition specialists and asset managers are responsible for obtaining the land for new wind development, as well as administering the land once it has been purchased or leased. They coordinate the efforts of permitting specialists, lawyers, engineers, and scientists to ensure that the wind farm is built on time and within budget. Typically, they are employed by a wind development company or the company that owns and operates the wind farm.

After land has been obtained and wind turbines have been manufactured, the turbines need to be delivered to the wind farm. Because of the extremely large size of turbine components, transporting them is no easy feat. Most wind farms are in relatively remote areas of the country; it takes a great deal of planning to transport the turbine parts there in a cost-efficient, timely manner. Getting wind turbine components from the factory to the construction site requires the hard work of teams of logisticians, heavy-load truck drivers, and, occasionally, rail and water freight movers.

In the wind energy industry, some OEMs handle their own logistics and transportation. Others contract these services out to third-party companies, many of which have extensive experience at moving heavy freight in other industries.

Job duties

Land acquisition specialists are responsible for designing and implementing land acquisition plans for new wind development sites. Land acquisition specialists work closely with landowners, local governments, and community organizations to gain support for proposed wind projects. They also work with lawyers, permitting specialists, engineers, and scientists to determine whether sites are suitable for wind farm development and to lead the process of purchasing or leasing the land.

Asset managers are responsible for representing owner interests, especially by maximizing profits, in wind-farm projects. They ensure that the land is used in the most efficient way possible and oversee the project's finances, budget, and contractual requirements.

Logisticians are responsible for keeping transportation as efficient as possible. Because wind farm projects are expensive and run on tight schedules, any time spent waiting for delayed turbine components costs money. Logisticians have to work extensively with both the manufacturer and construction team to develop an optimized schedule for delivering turbine components.

One difficulty logisticians face is the differing regulations individual States have for trucking heavy freight within their borders. Some require State trooper escorts, and others do not even allow trucks over a certain tonnage over their State lines. 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.

Education and training

Land acquisition specialists and asset managers are expected to have a bachelor's degree or higher in business, real estate, law, engineering, or a related discipline. Experience and familiarity with the permitting process and an understanding of tax and accounting rules is desirable. Companies will typically hire people with experience in land acquisition and management and train them to their specific needs. Experience in the energy industry is helpful.

Most logisticians have a bachelor's degree, usually in a field like engineering, business, or economics. Typically they also attend postgraduate programs in logistics or supply chain management. Additionally, many logisticians receive on-the-job training to learn about supply chain issues unique to the wind energy industry.

Earnings

There are no earnings data available for land acquisition specialists and asset managers. However, similar occupations in commercial real estate and property management pay a median salary of $74,010.

Logisticians working in the management, scientific, and technical consulting services industry group, which includes many firms that work primarily in logistics, had a median annual wage of $65,950 in May 2009. This wage is not specific to the wind energy industry.

Scientists

Wind energy is one of the most environmentally friendly sources of power generation available today. However, turbines, like any large construction project, have an im-

pact on the environment. The permitting process requires that environmental impact studies be conducted before work begins on a wind farm. In addition, scientific research is necessary to ensure that a site is suitable for erecting turbines and that the turbines are configured to maximize electricity in varying wind conditions.

Scientists in the wind industry may be employed by a development company or contracted for a specific project. Some contractors work for companies that specialize in environmental consulting for wind power projects. Scientists travel frequently, spend substantial amounts of time at proposed wind-farm sites, and work with local, State, and Federal regulators throughout the permitting study process.

Wind farm development requires the work of scientists in various specialties, including atmospheric scientists, biologists, geologists, and environmental scientists. They work along with engineers, technicians, and project managers to ensure that the site is suitable for the development of a wind farm.

Job duties

Scientists employed by the wind power industry spend a large part of their time in the field. Typically, the scientists are used as experts to ensure that a site is suitable for a proposed wind farm. They often start with a site visit to gather preliminary data and conduct desktop studies by use of computer models and other techniques. Field studies are necessary to ensure that the wind turbines will have little impact on the surrounding environment and can safely generate enough electricity to be profitable.

Atmospheric scientists, often referred to as meteorologists, 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. These 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, they help decide the placement of turbines at the site to ensure that the greatest possible amount of energy is obtained from the wind. Atmospheric scientists in the wind industry are in relatively high demand, although they are a small segment of the wind-energy workforce.

Wildlife biologists 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 are a serious threat to local and migrating bird and bat populations. Biologists must make sure that the impact on these populations is minimal. They spend a great deal of their time outdoors at the site, cataloging the surrounding wildlife and making recommendations on how to avoid interfering with local ecosystems. Formal permitting processes exist at the Federal and State levels. Wildlife biologists supervise the development of reports on environmental impact.

Geologists spend a large part of their time in the field, identifying and examining the underlying topography of a proposed wind farm. Because of the size and weight of modern turbines, geologists must ensure that the ground at the site can support such structures. They study the ground, make recommendations on where to place the turbines, and provide guidance on how to construct the foundations.

Environmental scientists work with wind farm developers to help them comply with environmental regulations and policies and to ensure that sensitive parts of the ecosystem are protected. They use their knowledge of the natural sciences to minimize hazards to the health of the environment and the population. These scientists are heavily involved in the study and permitting phases of development.

Education and training

Although a master's degree is often preferred, a bachelor's degree, depending on the specialty, typically is sufficient for an entry-level position. A Ph.D. is desirable for scientists in certain fields who oversee environmental impact and site suitability studies and provide expert guidance to ensure that wind turbines are constructed for optimal efficiency and minimal environmental impact.

Computer skills are essential for the majority of these positions because scientists use them for data analysis and integration, digital mapping, remote sensing, and construction of computer models. Scientists in certain specialties, such as atmospheric scientists, geologists, environmental scientists, are usually certified or licensed by a State licensing board.

Earnings

Earnings for scientists depend on a number of factors including the following: specialty, education, experience, and level of involvement with a project. Scientists may be employed by a wind farm developer or a consulting firm, or be contracted for specific projects. Median earnings for selected scientists are noted in the following tabulation. As with other occupations listed in this report, these figures are not specific to the wind power industry.

Occupation	Median annual wages
Atmospheric and space scientists	$84,710
Zoologist and wildlife biologists	56,500
Geoscientists, except hydrologists and geographers	81,220
Environmental scientists and specialists, including health	61,010

Construction Occupations

Erecting wind turbines requires the efforts of many skilled construction workers. The work begins before the turbine components arrive on site: construction laborers and construction equipment operators are responsible for building local access roads and the foundations that support the turbines.

After the turbine components arrive, crane operators set the first tower segment vertically onto the ground, where other workers secure it to the foundation. The remaining tower segments are then stacked atop one another and fastened together. When the tower has been erected, crane operators carefully lift the nacelle and the blades. The nacelle is placed on the top of the tower, and the blades are attached to the turbine's hub.

Job duties

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 to break up the ground on which the turbine will rest.

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

Construction equipment operators, with the help of construction laborers, are responsible for building accessible roads directly to the construction site, helping ensure that the wind turbine components can arrive without damage or delay. They use bulldozers, road graders, and other equipment to set up the construction site.

Crane operators are necessary in building a wind farm because the components are so large. They use their cranes to lift the pieces of the turbine off the trucks

as they arrive. Crane operators are integral to the actual construction job, as well. For example, they operate cranes to stack the tower segments and lift the blades to the hub.

Electricians are needed to 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.

Education and training

Although some construction laborer jobs have no specific education or training requirements, some construction workers receive more formal training in the form of apprenticeships. These programs consist of several years of classroom and on-the-job training. High school classes in English, mathematics, physics, mechanical drawing, blueprint reading, welding, and general shop can be helpful to prepare for the apprenticeships. Many construction laborers' skills are learned on-the-job and by assisting more experienced workers.

Local contractors may or may not have worked with wind turbines before. However, construction workers and wind turbine service technicians employed by companies specializing in wind farm development handle the more technical operations and usually have extensive experience in the wind industry.

Construction equipment operators and crane operators learn their skills through on-the-job training, apprenticeships, or, for some, union instruction. In addition, the operators are expected to be certified to operate their equipment. Crane operators need to be highly skilled, especially when handling large, expensive cargo like wind turbine components.

Most electricians learn their trade through apprenticeship programs that combine on-the-job training with related classroom instruction. Apprenticeship programs usually last 4 years, and, in them, electricians learn skills such as electrical theory, blueprint reading, electrical code requirements, and soldering. Depending on the State, electricians might have to pass an examination that tests their knowledge of electrical theory, the National Electrical Code, and local and State electrical and building codes.

Earnings

BLS does not have wage data specific to construction occupations that involve working on wind farms. However, the earnings of workers in these occupations are comparable to those of workers in the construction sector as a whole. The earnings in the following tabulation are for workers in the construction of power and communication lines and related structures, which include wind turbines, because some workers, like electricians, can work in other industries with different earnings.

Occupation	Median annual wages
Construction laborers	$29,110
Operating engineers and other construction equipment operators	39,530
Crane and tower operators	47,170
Electricians	49,800

Project Managers

It takes a large number of people to build a wind farm, and managing the project can be a difficult task. Project managers oversee the construction of the wind farm from site selection to the final installation of turbines. A project manager will oversee a diverse team, including engineers, construction workers, truck drivers, crane operators, and wind technicians. Project managers must have excellent attention to detail and be good at time and resource management.

Project managers usually have experience in construction and management or in engineering. They must be familiar with all aspects of wind farm development: from budgeting, site selection, site studies, and permitting processes and safety policies to construction and transportation of wind turbines.

Job duties

Project managers are employed by larger construction companies, energy companies, or land owners and work under contract or as salaried employees. Because of the size and complexity of some wind farms, project managers may manage portions of the construction, such as site clearing, foundation construction, or tower erection. These managers report to a senior project manager or site manager.

Project managers split their time between the wind farm site and their office, which may be located onsite or offsite. Primary office responsibilities include managing permitting, contracting, and the budget. At the construction site, the project manager monitors progress and performs inspections for quality control. Project managers oversee the contracting process and manage various

contractors and subcontractors. They are responsible for promoting a safe work environment and ensuring strict adherence to site safety policies.

Education and training

Experience in construction, particularly wind farm construction, is vital for project managers. Most managers have experience working on several wind farm projects before they are selected to manage one. Education is becoming important, and most project managers hold a bachelor's degree or higher in construction management, business management, or engineering. Advanced degrees, such as an MBA, are becoming more common.

Because experience is so important for these positions, years of experience may substitute for some educational requirements. However, this is becoming increasingly rare, as projects grow more complex and employers place more emphasis on specialized education. New graduates from construction management or engineering programs may be hired as assistants to project managers to gain experience.

Earnings

Earnings for construction managers of large projects, such as wind farms, vary with the size of the project, geographic location, and experience. The median annual salary for construction managers is $82,330, but site managers of wind farm projects typically make over $100,000.

Occupations Relevant to Operation and Maintenance

The reliability of the turbine system is essential to a power project. Because of the complexity and expense of the equipment, operation and maintenance services are critical to keeping the turbine functioning properly. Safety also is a primary concern: the large size and speed of turbine blades can present hazards to nearby turbines or people who are in the area. Operating a turbine requires someone to schedule site personnel, observe turbine operation, and deal with equipment failure. Maintaining it requires periodic equipment inspections, sensor calibration, cleaning, and unscheduled repairs of malfunctioning components. These tasks are performed by wind turbine service technicians, who must climb the towers and ensure that the wind turbines continue to operate reliably.

Wind Turbine Service Technicians

Wind turbines are extremely complex machines, made up of many different components. If any part fails, the wind turbine has to be shut down until repairs can be performed, and this lost operating time costs the owner money. To prevent these stoppages, wind turbine service technicians, also known as wind techs, are employed to inspect turbines and provide regular maintenance. Wind techs are capable of diagnosing and fixing any problem that could require the turbine to be shut down.

Many different companies employ wind turbine service technicians. The OEMs that design and manufacture the turbines offer warranties on their turbines usually lasting anywhere from 2 to 5 years.8 They employ wind techs to perform maintenance and address problems during the warranty period. There are also many companies that specialize in performing turbine maintenance and employ wind techs to provide this service to wind farm owners.

Most wind farms are located away from populated areas, so technicians must be prepared to travel frequently or to live in remote locations for extended periods. Wind turbine service technicians may work at several different sites and travel among the sites to perform maintenance as needed.

Job duties

Wind techs are responsible for both regular maintenance and performing complicated repairs of wind turbines. The average workday is spent climbing and inspecting multiple turbines. Technicians work a schedule that rotates which turbines need to be inspected or maintained. Any problems they notice during the examination are reported and scheduled for repair.

Wind turbine service technicians do much of their daily maintenance work in the nacelle, where the gears and sensitive electronics are housed. Nacelles, however, are built very compactly, and wind techs must be able to work with little operating room. Inside the nacelle, turbine technicians regularly clean and lubricate shafts, bearings, gears, and other machinery. They also use handheld power tools and electrical measuring instruments to troubleshoot any faults in the generator.

Sometimes wind techs have to work outside, on the top of the nacelle. They might, for example, have to replace the instruments that measure wind speed and direction. When outside, turbine technicians can be hundreds of feet in the air and need to be extremely safety conscious. They wear harnesses that are attached to rings on the nacelle and move cautiously while working.

When performing repairs, wind techs might need a new component to replace the broken one. If so, they must drive to the wind farm's parts storage facility and pick up a new component or have another worker deliver it to the turbine site. The turbine technician sometimes has to carry the new piece while climbing up to where it is installed.

Wind turbine service technicians are also responsible for administration of the site. These technicians may be responsible for anywhere from one turbine to hundreds of turbines on a large farm. They are responsible for ordering spare parts, and ensuring there is a proper inventory of parts available for needed repairs.

Education and training

The wind energy industry in the United States is relatively young, so there is no one way to be trained as a wind tech. Wind techs need to have mechanical skills and the aptitude to understand how a turbine functions, so some wind techs come from technician jobs in other industries. Experience or training as an electrician also is beneficial.

As formal training programs are developed, employers are placing more emphasis on wind-specific education. Educational institutions—specifically, community colleges and technical schools—are beginning to offer 1-year certificate and 2-year degree programs in wind turbine maintenance. In certificate programs, students take classes in basic turbine design, diagnostics, control and monitoring systems, and basic turbine repair. For a 2-year associate degree, students complete the aforementioned types of classes in addition to general-education courses. Some programs also give students hands-on training and practice on school-owned turbines and machinery.

Although there is no standard certification or course of study, organizations such as AWEA are developing guidelines on the core curriculum and skill sets necessary to work as a wind turbine service technician. AWEA plans to create a list of accredited programs that adhere to a specified curriculum and adhere to certain standards.

In addition to having technical knowledge, wind techs must be physically fit. Climbing up and down the ladders inside turbine towers, even with load-bearing harnesses, can be extremely strenuous. Wind turbine service technicians will often climb several towers during the course of a typical workday, and their bodies, especially their shoulders, must able to withstand this strain.

Earnings

BLS does not currently have earnings data for wind turbine service technicians. Data should be available in several years. According to industry sources, however, wind techs usually have starting salaries between $35,000 and $40,000. Wages and benefits vary by employer and geographic location.

Industry sources report that there is currently a shortage of trained wind techs. Because many different companies are competing to hire these workers, the most experienced wind techs can command relatively high salaries.

Occupations Supporting Wind Power

The growth of the wind power industry in the United States presents many opportunities for job creation. Jobs in this industry are located in every State in the country and cover a wide variety of occupations. This report has highlighted occupations in manufacturing, project development, and operation and maintenance, but the wind industry employs people in many other occupations as well. As with any complex project, support staff is necessary to ensure success.

The wind turbine supply chain consists of many different manufacturers of varying sizes. Although many of the companies in the supply chain do not concentrate on wind power, wind-power-related jobs in these companies do contribute to the industry. The process starts with the raw materials that are made into individual turbine components. Foundry workers are the first part of the wind turbine supply chain, casting metal, plastics, and composites out of raw materials.

Professional and administrative positions are vital to supporting wind power. Jobs in these fields include secretaries and receptionists, human resources specialists, accountants and auditors, lawyers, and managers of many different types. 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 secured and maintained, it is necessary to have janitors, maintenance workers, and security guards. Janitors and custodians are responsible for the cleaning and upkeep of facilities; security guards ensure that the facilities are free of unauthorized people and that problems are reported as soon as they occur. Maintenance workers make sure that machinery and equipment are kept in safe operating condition and repair broken equipment.

Conclusion

Jobs related to wind power are a potential source of new employment opportunities. Renewable energy is a key piece of the "green economy," and wind power, which supplies thousands of jobs in the United States, is the fastest growing sector in renewable energy.

This report examined the three major phases of a wind power project: manufacturing, project development, and operation and maintenance. All three are expected to experience rapid growth for the foreseeable future, as wind becomes a more common source of electricity generation for the Nation. The benefits of this expansion will be noticeable in the manufacturing and construction sectors, which have been hit particularly hard by the recent economic recession. Jobs in the wind industry will be available to people with a broad range of education and experience levels.

Although BLS data are not yet available, growth in the wind energy industry is evidenced by the rapid increase in wind-generating capacity over the past several years. The industry's growth should increase demand for skilled workers. Companies employ wind energy workers in most States: manufacturing occurs in areas where wind power is not feasible, and construction and operations jobs are available in areas where wind is abundant. In addition to the occupations covered in this report, the future holds opportunities for more types of occupations. And, as offshore wind projects are started and people begin to take advantage of "small wind" projects, even more jobs could be created.

Notes

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