Careers in Solar Power

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Sunlight is the most abundant source of potential energy on the planet. If harnessed properly, sunlight could easily exceed current and future electricity demand. According to the U.S. Department of Energy, every hour, enough energy from the sun reaches Earth to meet the world's energy usage for an entire year.[1] Creating solar power by converting sunlight into electricity would lower emissions from electricity generation and decrease long-term energy costs. As solar power becomes more cost-effective, it has the potential to make up a larger share of growing U.S. energy needs. And as it expands in usage, there will be a growing need for more workers—manufacturing workers to make solar panels, construction workers to build power plants, solar photovoltaic installers to install solar panels, and so on.

This article provides information on the process of generating solar power and details various occupations in the solar industry. The first section details a brief history of solar power in the United States, followed by an overview of how solar power is generated, which entities use it, and the technology involved in supplying solar power.

The second section provides occupational information highlighting a brief job description of several noteworthy occupations in that are related to solar power; the credentials needed to work in the occupation, such as education, training, certification, or licensure; and wage data. Occupations are listed under relevant occupational categories such as manufacturing, construction, installation, etc.

Using the data from the U.S. Bureau of Labor Statistics (BLS), Occupational Employment Statistics program and the Solar Foundation, this article represents the second publication of articles in the Bureau's green careers series.

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Growth of solar power in the United States

Because of a growing interest in renewable energy and the increasingly competitive prices of alternative energy sources, solar power has received a lot of attention over the past several years. However, solar power generation itself is not new; it has been used for more than half a century, mostly on a small scale or for specialized purposes, such as generating electricity for spacecraft and satellites or for use in remote areas. Large scale solar generation was mostly developed in the 1970s and 1980s, and is considered a clean energy because of its lack of emissions. Continued growth is expected because solar power has many environmental benefits and is decreasing in price, which will allow it to become increasingly competitive with fossil fuels.

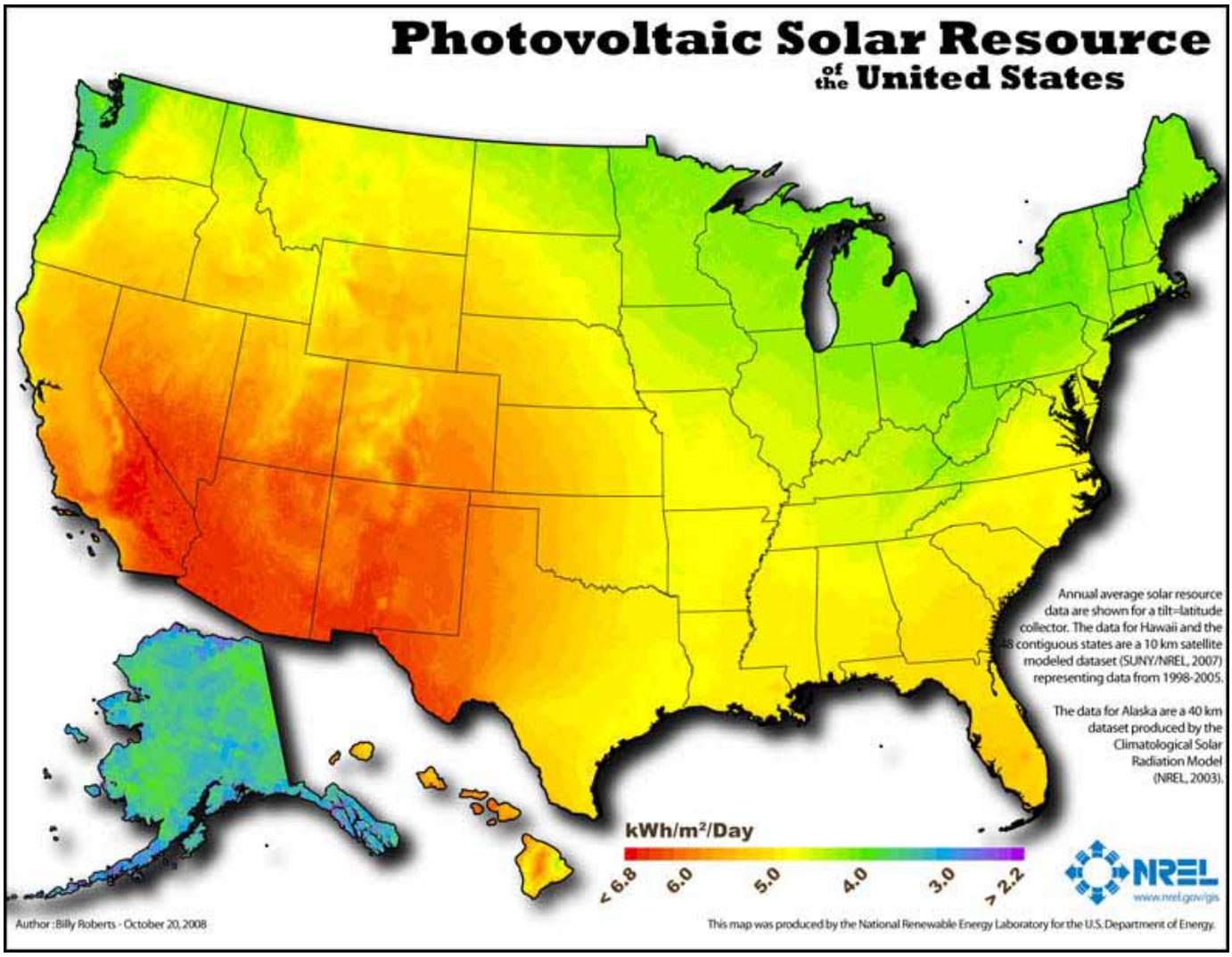
Illustration 1. Sunrise over a solar power plant

The relatively steep cost of solar power compared with traditional sources of electricity generation is caused by the high cost of manufacturing and installing solar panels. However, the cost of solar power has been trending downward as technology has improved and manufacturers have learned how to improve production efficiency. In addition, as solar power generation becomes more widespread, the cost of installing solar-generation capacity will continue to fall. And as the price of fossil fuels increases, solar power will become more cost effective relative to traditional sources of energy.

The solar power industry has experienced rapid growth in the past decade. According to the Solar Energy Industries Association (SEIA), total U.S. solar electric capacity surpassed 2,000 megawatts in 2009, enough to power over 350,000 homes. In 2009 alone, the residential market doubled in size and three new concentrating solar power (CSP) plants opened in the United States, increasing the solar electric market by 37 percent.[2] Despite this growth, solar power is still a minute portion of total energy generated in the country. In 2009, solar power provided less than 1 percent of total electricity generated in the United States.[3]

The Bureau of Labor Statistics (BLS) does not currently have employment data for the solar power industry.[4] However, the Solar Foundation, a nonprofit organization that promotes the use of solar energy technologies to help meet the world's energy needs, estimates that in August 2010, 93,000 workers spent more than half of their work hours on projects related to solar power.[5] The solar industry includes workers in science, engineering, manufacturing, construction, and installation. Scientists, for example,

Map 1. Available solar energy in the United States



are involved in the research and development of new and more efficient materials, and engineers design new systems and improve existing technologies. Manufacturing workers make the equipment used in solar power generation, such as mirrors and panels. Construction workers build solar power plants. Electricians, plumbers, and solar photovoltaic installers install residential and commercial solar projects. The Solar Foundation estimates that the largest growth in the solar industry in 2011 will be in occupations in solar installation, including photovoltaic installers and electricians and roofers with experience in solar installation.[6]

Solar power generation

Solar power is a versatile means of generating electricity. It can be used for such purposes as heating water, heating and air conditioning homes and commercial buildings, and powering streetlights. Because sunlight is readily available almost everywhere and doesn't require fuel or a connection to a power grid (an interconnected network used to deliver electricity from suppliers to consumers), solar power is particularly useful for supplying power to remote areas and to some portable devices.

Solar power is used to generate large amounts of power on a utility scale and to supply individual residences and businesses with electricity. This report focuses mainly on utility-scale, commercial, and residential solar power.

Utility-scale solar power plants supply large amounts of electricity to the power grid along with traditional sources of power, such as coal and natural gas plants. Solar power plants typically generate several megawatts of power, comparable to small or medium coal- or gas-fired plants. Plants only now in the planning stages are expected to produce several hundred megawatts,[7] which would be comparable to a medium to large coal plant or nuclear plant.

Commercial solar power is used by business establishments, such as office buildings, warehouses, and retail stores, which are able to install large groups of solar panels known as photovoltaic (PV) arrays, on unused land, rooftops, or parking structures. These panels supplement the building's power supply, and, at times, may generate more electricity than the building consumes. Often, this excess power can be sold back to the local utility company.

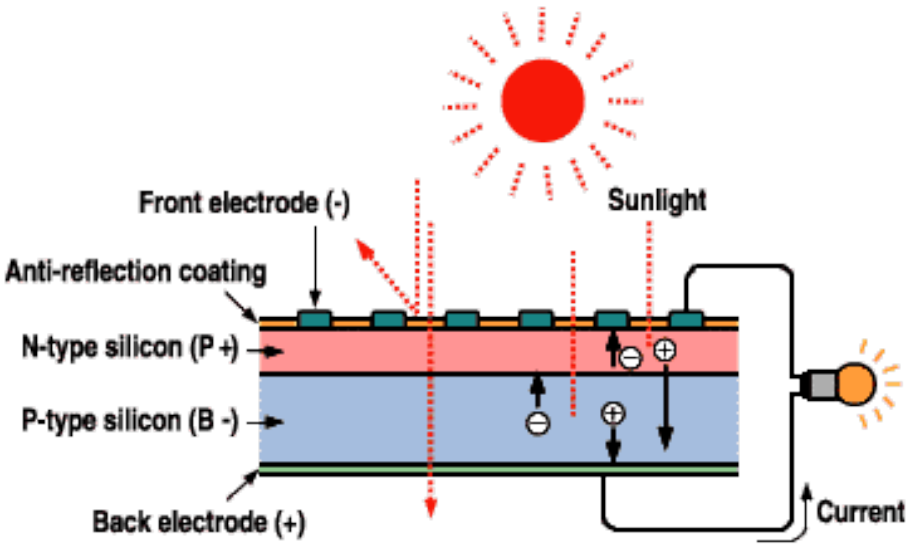
Residential solar power is generated by homeowners who have solar panels installed on their roofs in order to provide power to their homes. This form of solar power is increasing in popularity. Residential solar power usually must be supplemented by traditional electricity from the power grid to provide additional electricity when the solar panels cannot meet energy needs, such as when it is nighttime or extremely cloudy.

Although some areas of the United States are better suited for solar power than others, solar energy can be harnessed in any geographic area because of the sun's vast reach. In 2009, California had by far the most solar power capacity at 1102 megawatts, followed by New Jersey with 128 megawatts.[8] Nearly all states in the United States receive more sunlight per square mile than Germany, the world's leading producer of solar energy.[9] Manufacturing of solar power equipment and components is located throughout the United States, with large plants in Massachusetts, Michigan, Ohio, Oregon, California, Wisconsin, Tennessee, New Mexico, Colorado, Georgia, and Texas. Other large solar panel manufacturing facilities are planned to begin construction over the next few years in many states.

Methods of solar power generation

There are two basic methods for generating electricity from solar power. The first method uses photovoltaic

Diagram 1. The photovoltaic effect



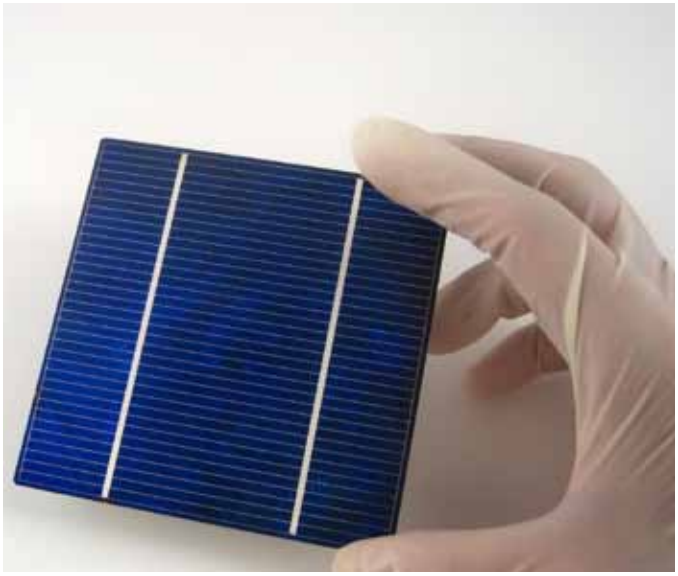


Illustration 2. A solar cell

(PV) solar panels to generate electricity directly from sunlight. The second method is known as concentrating solar power (CSP) and converts sunlight into heat to produce steam, which is then fed through conventional steam-turbine generators to generate electricity.

Photovoltaic panels have traditionally been used for smaller scale electricity generation, particularly for residential or commercial use in individual buildings or complexes, while CSP is used for utility-scale electricity generation in solar power plants. However, photovoltaic solar plants recently started generating electricity in California, Illinois, New Jersey, Nevada, and Florida. CSP is also being adapted for smaller scale electricity generation.

Photovoltaic solar power

Modern photovoltaic solar cells were developed in the 1940s and 1950s, and the technology has evolved rapidly over the past several decades. The space programs of the United States and the Soviet Union first used photovoltaic cells as a source of energy to generate electricity for satellites and spacecraft. Solar energy is still used to power the International Space Station and the vast majority of satellites. Photovoltaic panels have also proven useful for providing electricity to remote locations that are not supplied by a local electric utility.

Photovoltaic power uses solar cells that convert the energy of sunlight directly into electricity through the photovoltaic effect. (See diagram 1.) The photovoltaic effect is a process by which light from the sun hits a solar cell and is absorbed by a semiconducting material such as crystalline silicon. The photons in the sunlight knock electrons loose from their atoms, allowing them to flow freely through the material to produce direct electric current (DC) electricity. For household or utility use, an inverter must be used to convert the electricity to alternating current (AC).

The individual solar cells are arranged onto a solar panel. The solar panel is coated in glass or another laminate to protect the cells from damage. A new technology allows solar panels to be placed on a thin strip of backing, usually aluminum, and covered with a plastic film, which decreases the weight and cost of a solar panel. These thin-film solar panels are becoming more common, although traditional glass- or laminate-coated panels continue to make up the majority of the solar panel market.

Usually, several panels are arranged into an array, which can be scaled to produce enough capacity to generate the desired amount of power. A single cell can produce enough electricity to power a small device, such as an emergency telephone, but larger arrays are required to power a house or building. Utility-scale photovoltaic plants consisting of thousands of solar panels are a more recent occurrence.

Concentrating solar power

The first large-scale solar power plants in the United States were concentrating solar power (CSP) plants. Built in the California desert in the 1980s and 1990s, these plants are

Illustration 3. Parabolic trough solar concentrators

Diagram 2. Parabolic trough solar power plant

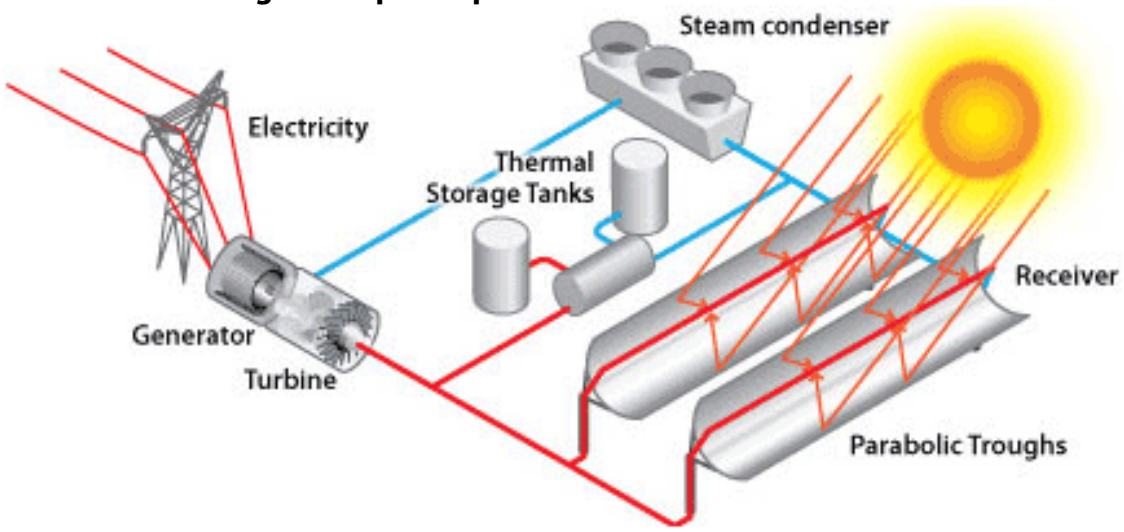
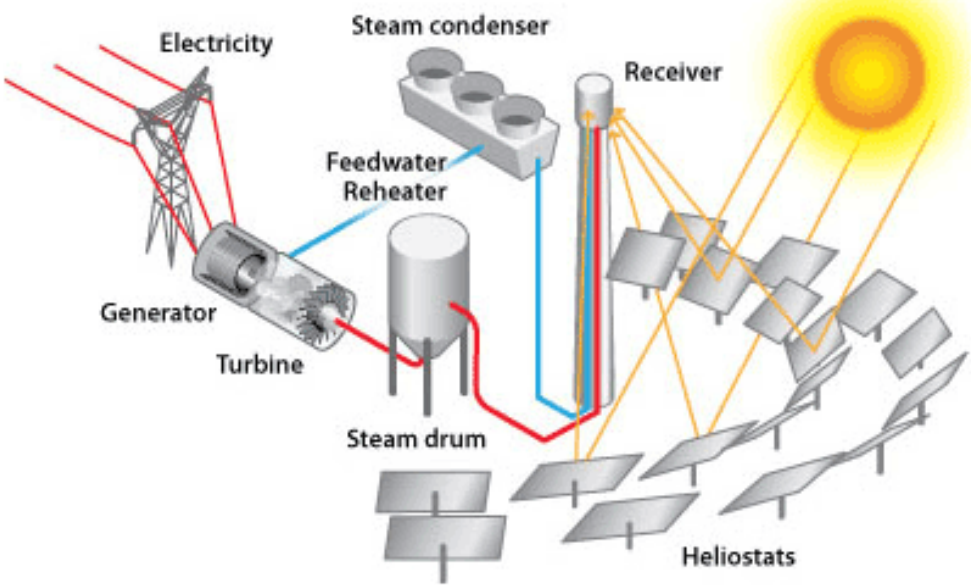


Diagram 3. Solar power tower plant



still among the largest, most powerful solar generating plants in the world. Several plants have also been in operation since the 1980s in the southwestern United States, and many more are currently in the planning and construction stages.

Although there are several different CSP technologies, they all involve reflecting sunlight onto a focal point that contains a heat-transfer material. The heat-transfer material, usually synthetic oil or molten salt, is collected in a heat storage unit and eventually used to create steam that powers conventional generators. One advantage of CSP is that at night or on extremely cloudy days, the conventional generators can be run on natural gas or petroleum, allowing the plant to continue to generate power when the sun is not shining.

All CSP plants consist of arrays of mirrors. The first type of CSP technology (still used today) works through the use of *parabolic troughs*, long, curved mirrors that move to follow the path of the sun, and focus the sun's heat onto a tube in front of the mirror. This dramatically increases the temperature of the heat-transfer material, which in turn boils water and creates steam that drives a generator. (See diagram 2.)

Solar power towers, another type of CSP technology, were first used at experimental power plants in the California desert during the 1980s and 1990s; improved solar power towers are currently being developed for newer CSP plants. In these plants, a large array of flat mirrors (called heliostats) is focused on a central tower that contains the heat-transfer material. The transfer material is pumped into storage tanks that can contain the heat for up to a day. It is then passed through a heat exchanger, where it produces steam that drives the generators. (See diagram 3.)

Engineers and scientists have recently developed a new

form of CSP technology called the *dish system*. In this system, the mirrors are arranged in a parabolic shape, similar to that of a satellite dish, which focuses the heat onto a central receiver mounted above the center of the dish. (See diagram 4.) The receiver contains an engine known as a Stirling engine that converts heat to mechanical power by compressing a cold fluid, which could be water or synthetic oil. The heating of the fluid causes it to expand through a turbine or a piston, which produces mechanical power. An electric generator or alternator then converts the mechanical power into electricity. Large scale electricity is produced by arranging several dishes into a larger array. New power plants using this technology have recently been approved for construction in California.

The *linear Fresnel system* is one of the newest CSP technologies. This system is similar to the parabolic trough system, but it uses multiple rows of flat mirrors to focus light onto a set of tubes, increasing the temperature of the heat-transfer fluid. (See diagram 5.) The advantage of the linear Fresnel system is that it is much less expensive to manufacture flat mirrors than curved ones.

Solar water heating

Solar power can be used for another important purpose: the heating of water for residential, commercial, or industrial purposes. Residential solar water heaters generally consist of roof-mounted solar water collectors that directly heat water using sunlight or indirectly heat water by using solar collectors to increase the temperature of a heat-transfer material and pump it to a heat exchanger, which creates the hot water. Solar water heating systems may be used to provide hot water to a home, a swimming pool, or for commercial purposes.

Solar water heating systems are best suited to warm climates, but they can be effective in colder climates as well. Most systems provide a majority of a home's hot water needs, but are backed up by a conventional water heater for times when there is a lack of sunlight.

Usually, solar installers mount the thermal collectors for solar water heating using similar equipment as used to install photovoltaic panels, but thermal collectors are

Diagram 4. Solar dish power plant

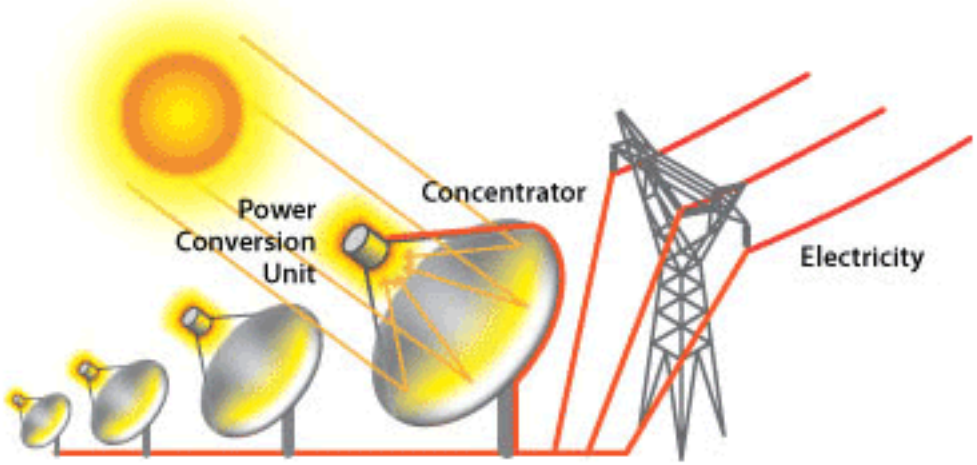
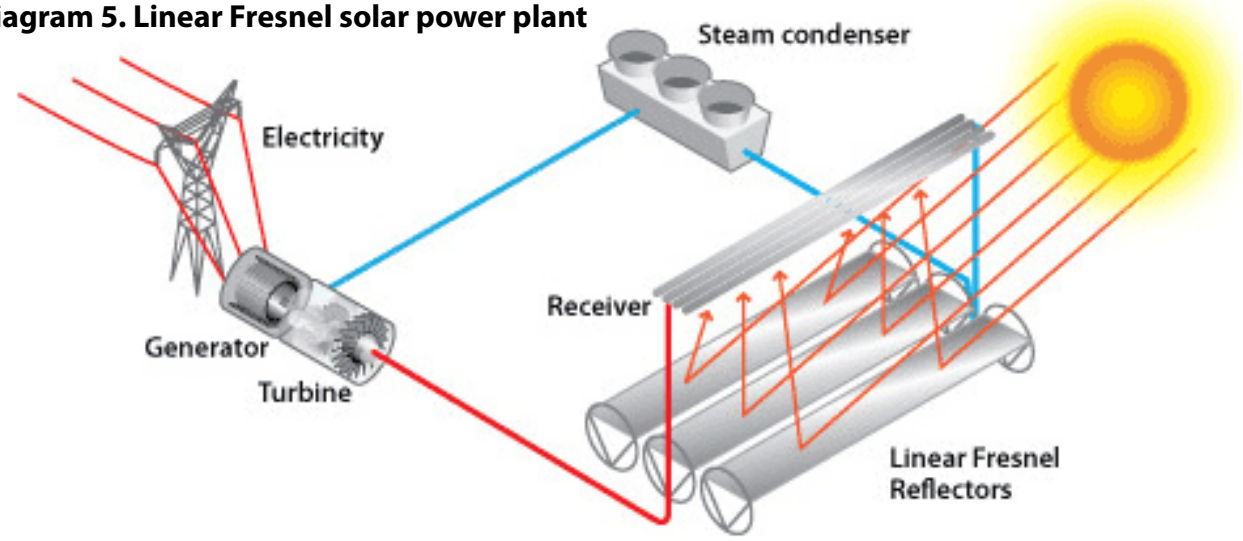


Diagram 5. Linear Fresnel solar power plant



used instead of panels. A plumber is needed to connect water pipes to the plumbing system of the house, pool, or commercial building.

Occupations in solar power

The solar power industry employs a wide range of occupations in a number of major industry segments: research and development, manufacturing of solar power materials, construction of solar power plants, operation of solar power plants, and solar power installation and maintenance. Sales occupations are also integral to the solar power products industry.

Following are descriptions of the most common jobs in the solar power industry; for each occupation, job duties are listed, along with the credentials needed for the occupation, including education, training, certification, or licensure. *Certification* demonstrates competency in a skill or set of skills, typically through work experience, training, the passage of an examination, or some combination of the three. *Licensing* is done by individual states, and typically requires the passage of an examination in addition to fulfillment of eligibility requirements, such as a minimum level of education, work experience, training, or the completion of an internship, residency, or apprenticeship.

In addition, wage data are included in the occupation descriptions. Although BLS does not have wage data specifically for occupations in the solar industry, BLS is currently in the process of collecting data to measure green jobs. This is expected to be available in 2012. The wages listed represent the larger industry or industry group that would employ solar power workers, when applicable. Wage data do not include benefits or other compensation.

The majority of the occupations listed here are not specific to the solar power industry—they exist in many other industries as well. Although many of these occupations require special skills unique to solar power, skills can be acquired in other industries in most cases. For many positions, experience in other industries is desired by employers in the solar power industry. For example, solar photovoltaic installers need to have specialized knowledge and training, but many installers have previous experience as roofers, electricians, or construction workers.

Occupations in scientific research

Solar power is still gaining popularity and acceptance, so research and development are key aspects of the industry. Continued research and increased returns to scale as production has increased have led to many developments that have decreased costs while increasing efficiency, reliability, and aesthetics. For example, new materials have been developed that allow for low-cost and lightweight thin-film solar panels that are less expensive to produce and easier to transport than glass- or laminate-coated solar panels.

Occupations in scientific research and development have become increasingly interdisciplinary, and as a result, it is common for physicists, chemists, materials scientists, and engineers to work together as part of a team. Most scientists in the solar industry work in an office or laboratory and also spend some time in manufacturing facilities with engineers and processing specialists.

Job duties

Physicists observe, measure, interpret, and develop theories to explain physical phenomena using mathematics. In the solar power industry, physicists work with chemists, materials scientists, and engineers to improve the efficiency of solar panels. Physicists also find new materials to use for solar panel generation, such as the thin-film photovoltaic solar panels.

Chemists investigate the properties, composition, and structure of matter and the laws that govern the reactions of substances to each other. Using this knowledge, chemists in the solar power industry are able to improve on solar cell design, develop new materials for making solar cells, or improve existing materials. They typically focus on semiconducting materials, which are usually silicon-based materials or organic compounds, because most solar panels are made of semiconducting materials and some

Illustration 4. Solar water heaters on a roof

newer thin-film panels are made out of organic materials.

Materials scientists study the structures and chemical properties of various materials to develop new products or enhance existing ones. Current research in the solar power field is focused on developing new materials, especially thin-film cells, and decreasing the cost of photovoltaic panels. Materials scientists are also seeking to increase solar panel efficiency. Efficiency refers to the percentage of available energy that is actually harnessed by the solar cells. Most modern solar cells can only harvest about 10 to 15 percent of solar energy, with some types of panels capable of 25 to 30 percent efficiency. Finally, material scientists are seeking to create building-integrated solar energy technologies that address common complaints about solar panels taking away the aesthetic appeal of a building because of their large and bulky nature.

Credentials

A doctoral degree is a necessity for scientists that conduct original research and develop new products; however, some workers may enter the scientific fields with a bachelor's or master's degree. Computer skills are essential for scientists to perform data analysis, integration, modeling, and testing. Certification or licensure is not necessary for most of these scientists.

Wages

BLS does not currently have wage data specific to the solar power industry. The table that follows shows wages for selected scientists for May 2010. The wages are median annual wages for the United States as a whole; wages vary by employer and location.

Selected scientific occupations	Median annual wages, 2010[1]
Physicists	$106,370
Chemists	68,320
Materials scientists	84,720

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

Occupations in solar power engineering

Engineers apply the principles of science and mathematics to develop economical solutions to technical problems. Their work is the link between scientific research and commercial applications. Many engineers specify precise functional requirements, and then design, test, and integrate components to produce designs for new products. After the design phase, engineers are responsible for evaluating a design's effectiveness, cost, reliability, and safety. Engineers use computers extensively to produce and analyze designs, and for simulating and testing solar energy systems. Computers are also necessary for monitoring quality control processes. Computer software developers design the software and other systems needed to manufacture solar components, manage the production of solar panels, and control some solar generating systems.

Most engineers work in offices, laboratories, or industrial plants. Engineers are typically employed by manufacturers of solar equipment and may travel frequently to different worksites, including to plants in Asia and Europe.

Engineers are one of the most sought-after occupations by employers in the solar power industry. According to the Solar Foundation, 53 percent of manufacturing firms reported difficulty in hiring qualified engineers in 2010.

Job duties

Materials engineers are involved in the development, processing, and testing of the materials for use in products that must meet specialized design and performance specifications. In the solar industry, they work with semiconductors, metals, plastics, glass, and composites (mixtures of these materials) to create new materials that meet electrical and chemical requirements of solar cells. They create and study materials at an atomic level, using advanced processes to replicate the characteristics of those materials and their components using computer modeling programs.

Chemical engineers apply the principles of chemistry to design or improve equipment or to devise processes for manufacturing chemicals and products. In the solar power industry, they design equipment and processes for large-scale manufacturing, plan and test methods of manufacturing solar cells, and supervise the production of solar cells. Chemical engineers in the solar industry typically focus on semiconductors or organic chemistry, since most solar panels are made of semiconducting materials and some newer thin-film panels are made out of organic materials.

Electrical engineers design, develop, test, and supervise the manufacture of electrical components. They are responsible for designing the electrical circuitry of solar panels and supporting devices for panels, such as inverters and wiring systems.

Industrial engineers determine the most effective ways to use the basic factors of production—people, machines, materials, information, and energy—to make a product or provide a service. In the solar power industry, they are concerned primarily with increasing productivity through the management of people, the use of technology, and the improvement of production methods of solar cells or mirrors. To maximize efficiency, industrial engineers study the product requirements carefully and design manufacturing and information systems with the help of mathematical models.

Mechanical engineers research, design, develop, manufacture, and test tools, engines, machines, and other mechanical devices. Engineers in the solar power industry work on the machines used in the manufacturing of solar panels. In the United States, solar photovoltaic manufacturing is highly automated. Machines do the majority of work: cutting semiconducting materials, such as crystalline silicon, into wafers, turning them into solar cells, and assembling the solar cells into solar panels. Besides machines, mechanical engineers also design and test the electric generators and pumps that are used in concentrating solar power plants.

Computer software developers are computer specialists who design and develop software used for a variety of purposes. In the solar power industry, computer software is used in forecasting weather and sunlight patterns to assess the feasibility and cost of generating solar power in a particular area. In power plants, software is used to monitor the equipment and to adjust the direction of mirrors or photovoltaic panels so that the maximum amount of energy is captured as the sun moves in the sky. Software developers are responsible for updating, repairing, expanding, and modifying existing programs.

Engineering technicians assist engineers with solving technical problems in research, development, manufacturing, construction, inspection, and maintenance. Their work is more narrowly focused and application-oriented than that of engineers or scientists. Engineering technicians who work in the research and development of solar panels or machines will build or set up equipment, prepare and conduct experiments, collect data, and calculate or record results. They may also help engineers or scientists to make prototypes of newly designed equipment or assist with computer-aided design and drafting (CADD) equipment.

Credentials

Engineers typically enter the solar industry with a bachelor's degree in engineering. However, because of the complexity of some systems, a significant number of jobs require a master's or doctoral degree. Engineers are expected to complete continuing education and keep up with rapidly changing technology.

Certifications are usually required and depend on the systems used by a particular manufacturer. Licensure as a professional engineer (PE) is desirable and often required, depending on an engineer's specialty.

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

Software developers typically have at least a bachelor's degree in computer science or a related discipline, combined with experience in computer programming and software design.

Engineering technicians typically have an associate's degree or certification from a community college or technical school. Technicians participate in on-the-job training and are closely supervised by engineers.

Wages

BLS does not currently have wage data specific to the solar power industry. However, BLS does have wage data for the Semiconductor and Other Electronic Component Manufacturing industry group, which includes production of solar panels. The following table shows BLS data for selected occupations in this industry group for May 2010. The wages shown are median annual wages for the United States as a whole; wages vary by employer and location.

Selected engineering and computer occupations in the semiconductor and other electronic component manufacturing industry	Median annual wages, 2010
Materials engineers	$86,380
Chemical engineers	92,820
Electrical engineers	92,070
Industrial engineers	83,620
Mechanical engineers	78,910
Software developers, applications	96,230
Electrical and electronics engineering technicians	51,060

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

Occupations in manufacturing for solar power

Manufacturing in the solar industry focuses on three technologies: concentrating solar power (CSP), photovoltaic solar power, and solar water heating. However, the vast majority of solar manufacturing firms focus mainly on photovoltaic solar power and producing photovoltaic panels. The production process for photovoltaic panels is more complex than for CSP components, and it involves complicated electronics. Making photovoltaic panels requires the work of many skilled workers, including semiconductor processors, computer-controlled machine tool operators, glaziers, and coating and painting workers. The manufacture of CSP mirrors includes many of the same occupations

Illustration 5. Workers in a clean room

Job duties

Semiconductor processors are workers who oversee the manufacturing process of solar cells. Semiconductors are unique substances, which act as either conductors or insulators of electricity, depending on the conditions. Semiconductor processors turn semiconductors into photovoltaic cells. The process begins with the production of cylinders of silicon or other semiconducting materials, which are called ingots. The ingots are sliced into thin wafers using automated equipment, and are sometimes polished. The wafers are then connected to metal strips and placed into the cells. These cells are then arranged into larger solar panels.

The electrical circuitry of solar cells is very small, and microscopic contamination can render the cell useless. Because of this, most of the manufacturing processes are automated, and it is important to have workers to monitor the equipment and make adjustments as necessary. They also perform necessary maintenance and repairs on equipment. Semiconductor processors test completed cells and perform diagnostic analyses. Workers are required to wear special lightweight outer garments known as "bunny suits" and spend most of their day working in clean rooms to prevent contamination of the cells and circuitry.

Computer-controlled machine tool operators are workers who run computer numerically controlled (CNC) machines, a machine tool that forms and shapes solar mirror or panel components. Some of the more highly trained CNC workers also program the machines to cut new pieces according to design schematics. CNC operators use machines to mass-produce components that require highly precise cutting. In the solar power industry, they manufacture precisely designed mirrors for CSP plants and many of the components of photovoltaic panels.

Welding, soldering, and brazing workers apply heat to metal pieces during the manufacturing process, melting and fusing them to form a permanent bond. Welders join two or more pieces of metal by melting them together. Soldering and brazing workers use a metal with a lower melting point than that of the original piece, so only the added metal is melted, preventing the piece from warping or distorting. Solar panels are made up of many small cells that are soldered to electric circuitry. This process may be automated, with workers monitoring the machines.

Glaziers are responsible for selecting, cutting, installing, replacing, and removing glass or glass-like materials. Photovoltaic panels are placed in an aluminum frame and are typically encased in glass or laminates to protect them from the elements. The glaziers are responsible for measuring and cutting the glass or laminate to cover the panel; securing it in place; and sealing it using rubber, vinyl, or silicone compounds. It is important to prevent the cover from cracking or scratching thereby reducing the efficiency of the solar panel.

CSP plants are made up of many highly reflective mirrors manufactured to exact specifications. Many of these plants use curved mirrors, which are challenging to produce. Glaziers are instrumental in the manufacturing, installation, and maintenance of these mirrors. Glaziers ensure the mirrors maintain maximum reflectivity in order to perform at desired levels. Because these mirrors are located outdoors and are expensive to make, glaziers must often refinish and refurbish them. Mirrors also break frequently, and glaziers produce the replacements.

Coating and painting machine setters, operators, and tenders apply coatings to solar panels, which can be a complicated process that must be done with a high level of precision. Mirrors in CSP plants are typically coated to protect them from the environment and to make them resistant to scratches and corrosion. Solar photovoltaic panels are also covered in protective coatings, and these coatings increase the efficiency of the panels. Special coatings, such as titanium oxide, make solar panels less reflective and therefore able to absorb more sunlight (or lose less sunlight.)

Before painting or coating a mirror or panel, workers prepare the surface by sanding or grinding away any imperfections. After preparing the surface, it is carefully cleaned to prevent any dust or dirt from becoming trapped under the coating. The coating is then applied by spraying it onto the panel. Many manufacturers apply coatings through an automated process. It is the workers' job to set up the systems, add solvents, monitor the equipment, and feed the pieces through the machines.

Coating and painting workers may be exposed to dangerous fumes from paint and coating solutions and other hazardous chemicals. Workers are usually required to wear masks and special suits to protect them from the fumes produced by paint, solvents, and other chemicals.

Electrical and electronics installers and repairers work on a number of the complex electronic equipment that the solar industry depends on for a variety of functions. Manufacturers use industrial controls to automatically monitor and direct production processes on the factory floor.

Electrical and electronic equipment assemblers put together the final products and the components that go into them. They are responsible for assembling the complex electrical circuitry in a photovoltaic panel, as well as assembling the components, such as inverters or controls, that connect to solar panels. Many of these assemblers operate automated systems to assemble small electronic parts that are too small or fragile for human assembly.

Industrial production managers plan, direct, and coordinate work on the factory floor. They determine which machines will be used, whether new machines need to be purchased, when overtime shifts are necessary, and how to improve the production process. They keep production runs on schedule, and are responsible for solving problems that could jeopardize the quality of the components.

Credentials

The level and type of training necessary for occupations in the solar power manufacturing process varies. Most production workers are trained on the job and gain expertise with experience. Workers in more skilled positions, such as computer-controlled machine tool operators, may attend formal training programs or apprenticeships. Experience working with electronics or semiconductors may be helpful for some of these occupations.

Industrial production managers are typically required to have college degrees in business administration, management, industrial technology, or engineering.

Wages

BLS does not track wage data specific to the solar power industry. However, BLS does track wage data for the Semiconductor and Other Electronic Component Manufacturing industry group, which includes production of solar panels. The following table shows BLS data for selected occupations in this industry group for May 2010. The wages shown are median annual wages for the United States as a whole; wages vary by employer and location.

Selected occupations in the semiconductor and other electronic component manufacturing industry group	Median annual wages, 2010[1]
Semiconductor processors	$32,880
Computer-controlled machine tool operators, metal and plastic	31,470
Welders, cutters, solderers, and brazers	27,590
Glaziers[2]	36,640
Coating, painting, and spraying machine setters, operators, and tenders	32,520
Electrical and electronics repairers, commercial and industrial equipment	47,480
Electrical and electronic equipment assemblers	27,500
Industrial production managers	97,330

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

[2] Wage data are not available for the industry group specified. Wages listed are for the occupation as a whole.

Occupations in solar power plant development

Building a solar power plant is complex and site selection requires years of research and planning. The proposed

site must meet several criteria: large, relatively flat site, adequate sunlight, and minimal environmental impact once built. Prior to beginning construction on a new solar plant, real estate brokers and scientists must ensure the site is suitable and that the proper federal, state, and local permits are obtained for construction of a power plant.

Job duties

Real estate brokers are instrumental in procuring land on which to build power plants. They are responsible for obtaining the land by purchasing or leasing it from land owners. Real estate brokers must work with local, state, and federal government agencies, community members and organizations, utility companies, and others that have a stake in the proposed power plant. They work alongside lawyers, accountants, and project managers. Real estate brokers also consult with atmospheric scientists to determine if the land is suitable for a solar power plant.

Real estate brokers in the solar industry must have specialized knowledge of property specifications for solar power plants and the regulations in place for obtaining the property. Currently, many large solar plants in the United States have been built on—or are proposed to be built on—federal lands, so brokers have to work with the Bureau of Land Management to obtain leases for these properties.

Illustration 6. Man at a solar power plant

Atmospheric scientists (including meteorologists) study the atmosphere and weather patterns. In the solar power industry, they study particular areas being considered for development of a solar power plant. Because the efficiency of solar panels and concentrating solar power plants is highly dependent on the weather of a particular area, atmospheric scientists are needed to study atmospheric and weather conditions prior to the development of plants or large commercial solar projects. They can help determine if solar power will be a cost-effective way to generate energy in a particular area by studying past weather patterns and using computers to create models of expected weather activity. Although many atmospheric scientists work for companies that develop large-scale solar projects, some work for smaller consulting firms that provide these services to individual customers who are considering installing solar power in their homes or small businesses.

Environmental scientists ensure that environmental regulations and policies are followed and that sensitive parts of the ecosystem are protected. Many solar power plants are built in desert areas that have fragile ecosystems and numerous protected species. Construction and operation of plants must have minimal impact on the surrounding environment. Environmental scientists use their knowledge of the natural sciences to minimize hazards to the health of the environment and surrounding population.

Credentials

Real estate brokers typically have a bachelor's degree or a higher degree in business, real estate, law, engineering, or a related discipline. Experience with obtaining land permits and an understanding of tax and accounting rules are necessary, as well as familiarity with local environmental and energy regulations. Experience working with relevant government agencies, such as the Bureau of Land Management, is also desirable. Companies typically hire people with experience in land acquisition and management and train them to their specific needs.

Atmospheric and environmental scientists typically need a bachelor's degrees, but scientists with a master's or doctoral degree are preferred, depending on the scale of the projects they work on. Many of these scientists are hired on for the length of specific projects, and more education and experience makes them more attractive to hire full time. Atmospheric and environmental scientists may also need to be licensed, depending on local regulations.

Wages

BLS does not currently have wage data specific to the solar power industry. The following table shows BLS data for selected occupations for May 2010. The wages shown are median annual wages for the United States as a whole; wages vary by employer and location.

Selected occupations in solar power plant development	Median annual wages, 2010[1]
Real estate brokers	$54,910
Atmospheric and space scientists	87,780
Environmental scientists and specialists, including health	61,700

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

Occupations in solar power plant construction

Once a site has been selected, civil engineers are responsible for the design of the power plant and related structures. When construction begins, workers are needed to build the actual plant. For a concentrating solar power (CSP) plant, large mirrors are arranged to catch and focus sunlight for power generation, therefore storage tanks, pipes, and generators must be installed before the plant is connected to the electrical grid. Photovoltaic plants are less complex, requiring installation of arrays of photovoltaic panels before they are connected to transformers and the grid. Construction managers have the responsibility of managing the entire construction process.

Job duties

Construction managers oversee the construction of solar power plants, from site selection to the final construction of the plant. They supervise a team of diverse occupations, including engineers, scientists, construction workers, and heavy-equipment operators. Construction managers are employed by large construction companies, energy companies, or utilities companies and work under contract or as salaried employees. Because of the size of a power plant and the complexity of the construction, a project manager will typically oversee several construction managers, who then supervise individual aspects of the construction.

The construction manager's time is split between working at the construction site and an office, which may be located onsite or offsite. Primary office responsibilities include management of permits, contracts, and the budget. At the site, the construction manager monitors progress and performs inspections for quality control. Construction managers oversee the contracting process and manage various contractors and subcontractors. They are responsible for ensuring a safe work environment where workers adhere to strict site safety policies.

Civil engineers design and supervise the construction of power plants. Solar power plants can take a number of forms and sizes. CSP plants are more like typical power plants and require incorporating large steam turbines and storage tanks, plus a large, flat area for the solar array. Photovoltaic plants are less complex, but are a challenge for engineers to design because the panels are optimally configured to efficiently harvest solar power. Engineers ensure that the land is graded properly and is flat enough to support large arrays of mirrors or photovoltaic panels. Civil engineers are also responsible for designing necessary infrastructure, including roadways, support structures, foundations, and plumbing systems.

Construction laborers perform a wide range of construction-related tasks. Most construction laborers specialize in one component of construction, such as metalworking, concrete pouring and setting, assembly, or demolition. Laborers prepare the site for construction by removing trees and debris. They are also responsible for monitoring and repairing compressors, pumps, and generators, and for erecting scaffolding and other support structures, as well as loading, unloading, identifying, and distributing building materials in accordance with project plans.

Construction equipment operators use machinery to move construction materials, earth, and other heavy materials at a construction site. Many plants require flat, unobstructed ground in order to line up the solar panels or mirrors, and equipment operators operate machinery to clear and grade the land. They also operate cranes to lift and place heavy objects, such as photovoltaic arrays, large mirrors, and turbine generators. They set up and inspect their equipment, make adjustments to the equipment, and perform some maintenance and minor repairs.

Welders who work in solar power plant construction are important for both CSP and photovoltaic plants. In CSP plants, the work of welders includes joining structural beams together when constructing buildings, installing the structures that support the mirrors, and joining pipes together. At photovoltaic plants, welders are instrumental in building the solar panel mounting systems. Panels must be mounted on the ground or on a roof using metal beams, and welders are responsible for attaching these beams together to form the mounts.

Structural iron and steel workers use blueprints to place and install iron or steel girders, columns, and other structures to form the support structures for power plants. These workers also cut the structures to proper size, drill bolts for holes, and number them for onsite assembly by construction workers or solar photovoltaic installers. The structures are then shipped to worksites where they will be erected by structural iron and steel workers on a construction site.

Credentials

In most construction occupations, workers are trained on the job. Laborers typically work under supervisors, who direct them to complete tasks. As laborers gain more experience and prove their abilities, they may move up to become supervisors. Equipment operators often learn on the job or complete a formal training program, or a combination of both. Certain equipment requires operators to be certified, which involves some training and testing to ensure competence and safety.

Construction managers are typically educated in construction management, business management, or engineering, and usually have experience working in construction. Experience is important for construction managers, so it may be substituted for some educational requirements. Large, complex projects such as power plants, however, require specialized education. Workers with a degree in construction management or engineering, but without significant experience, may be hired as assistants to construction managers.

Civil engineers have at least a bachelor's degree in civil or structural engineering. Lead engineers on large projects, such as power plants, have specialized experience and typically have at least a master's degree. Licensure as a professional engineer (PE) may be required.

Welders usually learn their trade through on-the-job training or a formal apprenticeship program, or they may attend a formal training program at a trade school or community college. There are many different techniques that welders may use that also require additional training. Structural steel and iron workers are typically trained on the job and may complete additional specialized training.

Wages

BLS does not have wage data specific to the solar power industry. However, BLS does track the wage of occupations in the Utility System Construction industry group, which includes construction of solar power plants. The following table shows BLS data for selected occupations in this industry group for May 2010. The wages shown are median annual wages for the United States as a whole; however, wages do vary by employer and location.

Selected occupations in the utility system construction industry group	Median annual wages, 2010[1]
Construction managers	$83,170
Civil engineers	74,620
Construction laborers	29,600
Operating engineers and other construction equipment operators	43,240
Welders, cutters, solderers, and brazers	45,990
Structural iron and steel workers	44,890

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

Occupations in solar power plant operations

Workers at solar power plants install, operate, and maintain equipment. They also monitor the production process and correct any problems that arise during normal operation. Concentrating solar power (CSP) plants require more workers than photovoltaic plants; photovoltaic plants can sometimes even be run remotely.

Job duties

Power plant operators monitor power generation and distribution from control rooms at power plants. They monitor the solar arrays and generators and regulate output from the generators, and they monitor instruments to maintain voltage to regulate electricity flows from the plant. Power plant operators communicate with distribution centers to ensure that the proper amount of electricity is being generated based on demand. They also go on rounds through the plant to check that everything is operating correctly, keeping records of switching operations and loads on generators, lines, and transformers. Operators use computers to report unusual incidents or malfunctioning equipment, and to record maintenance performed during their shifts.

Some CSP plants have a secondary source of power generation, such as natural-gas powered turbines, that will generate power at night or when the weather doesn't

Illustration 7. A solar array

allow for sufficient solar power generation. Power plant operators are responsible for monitoring this equipment and deciding when to switch from solar generation to the secondary source.

Pump operators tend, control, and operate pump and manifold systems that transfer oil, water, and other materials throughout the CSP plant. CSP plants use mirrors to heat fluids like molten salt or synthetic oil, which are pumped through the solar heating devices and into a heat-transfer device to produce steam.

Pump operators maintain the equipment and regulate the flow of materials according to a schedule set up by the plant engineers or production supervisors. The work tends to be repetitive and physically demanding. Workers may lift and carry heavy objects and stoop, kneel, crouch, or crawl in awkward positions. Some work at great heights, and most work is done outdoors.

Electricians are responsible for installing and maintaining the electrical equipment and wiring that connects the plant to the electrical grid. Electricians in power plants work with heavy equipment, including generators, inverters, and transformers. They must be familiar with computer systems that regulate the flow of electricity, and they must be comfortable with high-voltage systems.

Plumbers, pipefitters, and steamfitters install, maintain, and repair pipe systems. Pipe systems in power plants carry the heat-transfer material—synthetic oil or molten salt—throughout the plant and into special heat containment units. Other pipes carry steam from the heaters to the turbines that generate electricity. These pipes often carry materials at both high temperatures and high pressure. The workers monitor, regulate, and control flow through the popes using automatic controls.

Plumbers, pipefitters, and steamfitters need physical strength and stamina. They must frequently lift heavy pipes, stand for long periods of time, and work in uncomfortable and cramped positions. They often must work outdoors and in inclement weather conditions. In addition, they are subject to possible injuries brought on by falls from ladders, cuts from sharp objects, and burns from hot pipes or soldering equipment.

Electrical and electronics installers and repairers use electronic power equipment to operate and control generating plants, substations, and monitoring equipment. They install, maintain, and repair these complex systems.

Electrical engineers are responsible for controlling electrical generation and monitoring transmission devices used by electric utilities in power plants.

Credentials

Power plant workers generally need a combination of education, on-the-job training, and experience. Strong mechanical, technical, and computer skills are needed to operate a power plant. Certification by the North American Energy Reliability Corporation (NERC) is necessary for positions that could affect the power grid. Companies also require a strong math and science background for workers seeking highly technical jobs. Knowledge of these subjects can be obtained through specialized training courses.

Because of security concerns, many power plant operators are subject to background investigations and must have a clean criminal record. They must also be willing to submit to random drug testing. Electricians and pipefitters and steamfitters must be trained on the specific systems on which they work. They attend specialized training programs and undergo extensive on-the-job training.

Wages

BLS does not have wage data specific to the solar power industry. However, BLS does have wage data for occupa-

Illustration 8. Man wiring solar panels

tions in the Electric Power Generation, Transmission and Distribution industry group, which includes the distribution of electricity generated by solar power plants. The table that follows shows BLS data for selected occupations in this industry group for May 2010. The wages shown are median annual wages for the United States as a whole; wages vary by employer and location.

Selected occupations in the electric power generation, transmission, and distribution industry group	Median annual wages, 2010[1]
Power plant operators	$64,270
Pump operators, except wellhead pumpers	58,740
Electricians	59,020
Plumbers, pipefitters, and steamfitters	66,080
Electrical and electronics repairers, powerhouse, substation, and relay	66,230

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

Solar photovoltaic installers

Solar photovoltaic installers are key to the process of solar panel installation and maintenance. They use specialized skills to install residential and commercial solar projects. They are responsible for safely attaching the panels to the roofs of houses or other buildings and ensuring that the systems work. Solar photovoltaic installers must be able to work with power tools and hand tools at great heights, and possess in-depth knowledge of electrical wiring as well as basic math skills. When necessary, installers must be problem solvers, able to repair damaged systems or replace malfunctioning components. Safety is a priority when installing solar panels because installers run the risk of falling from a roof or being electrocuted by high voltage.

Solar photovoltaic installers are often self-employed as general contractors or employed by solar panel manufacturers or installation companies. Installation companies typically specialize in installing certain types of panels and provide some maintenance and repair services. When a solar panel system is purchased, manufacturers may provide the buyer with installation services or maintenance and repair work. Self-employed installers typically have training and experience with installing solar power systems and are hired directly by the property owners or by a construction firm.

Job duties

The main component of a solar installer's job is the preparation of the installation site. Before the installation process begins, a full audit of a structure is conducted, including a survey of the existing electrical system and developing safety procedures. The job is then designed based on the characteristics of the structure and the type of system being installed. After the layout and equipment are finalized, the permits are obtained from the relevant governments (local, state, federal, or a combination). If the installers do not do these preparations themselves, they must familiarize themselves with the site before they begin working on it.

Once installation begins, the proper safety equipment, such as a rope and anchor system, must be set up to prevent falls from the rooftop. Often, the building will have to be upgraded to support the solar panels; this may involve reinforcing the roof, replacing rafters, or installing supports to handle the added weight of the panels. The roof must be marked to show where the arrays will be placed, and holes are drilled in the roof to attach the mounting system. After the mounting system is in place, the solar panels can be installed. Workers use caution during installation because the panels are fragile, expensive, and weigh at least 40 pounds each. If the panels are damaged during the installation process, the company has to cover the cost of repair or replacement.

Credentials

Solar photovoltaic installers typically have a background in construction or as electricians. There is no formal training standard for installers, but courses are offered by a variety of institutions, such as trade schools, apprenticeship programs, or by photovoltaic module manufacturers. Training programs vary widely and can range from 1 day to several weeks. Many solar installers are licensed as general contractors and many are licensed by the North American Board of Certified Energy Practitioners (NABCEP). Certification, while not necessary, can improve the job prospects of installers, and many larger projects require workers to be certified.

Solar installers may work alongside roofers, electricians, and plumbers in order to learn the variety of skills needed to complete an installation. Many installers enter the field with previous experience in one or more of these fields. Because of the high skill level required, clients may also ask that both lead installers and those installers who work independently obtain a general contractor's license,

depending on regulations of the localities and states where they work.

Wages

BLS does not currently publish wage data available for solar photovoltaic installers, but these data are being collected. According to industry sources, solar installers usually have starting salaries between $30,000 and $40,000 per year. Installers trained as electricians or those that are licensed as general contractors can make significantly more. As with any occupation, wages and benefits vary by employer and geographic location.

Other occupations in solar panel installation and maintenance

Other occupations in solar installation and maintenance are site assessors, electricians, plumbers, and roofers. These workers are involved in the installation process but are not classified as solar photovoltaic installers. However, solar photovoltaic installers posses many of the same skills as these occupations and often have work experience in these fields.

Job duties

Site assessors determine how much energy can be harvested at a particular location and then make recommendations based on that assessment. Site assessors help determine the best type, size, and layout of solar panels, and help draw up plans for installation crews. Assessors may take readings of sunlight at a proposed location, review weather patterns, and calculate potential costs and savings. Site assessors are usually hired for commercial projects by companies that are making substantial investments in solar power and therefore want to ensure maximum benefits from the project. Some site assessors may consult with homeowners or solar installation companies on residential projects.

Electricians install and maintain all of the electrical and power systems in a home or business. They install and maintain the wiring and control the equipment through which electricity flows. Electricians are responsible for connecting the solar panels, inverter, and other equipment to a building's power supply. Electricians may or may not specialize in solar installation; however, most electricians that work with solar panels have some experience or training on solar power equipment. If a new building or house is being constructed with a solar power generating system, electricians may be responsible for installing the solar power system along with the electrical wiring system, or they may be responsible for simply connecting the solar equipment.

Plumbers install solar water heating systems. These systems replace or augment a conventional water heater and must be connected to a house's or building's plumbing. To install these systems, plumbers require specialized training to work with solar water heater equipment.

Roofers install and repair roofs, and they ensure that any cuts or holes made in the roof during the installation of solar panels and mounting racks are properly repaired and sealed. They may also assist with the installation of mounting systems and structural supports. Roofers typically work with a variety of materials including tar, asphalt, gravel, rubber, thermoplastic, metal, and shingles. Roofing work is very strenuous. It requires workers to be on hot roofs for long periods of time, and it carries the risk of falls and other injuries.

Credentials

Site assessors generally have past experience with electrical or roofing work or experience as solar photovoltaic installers. They receive on-the-job training as well as specialized training in the equipment and techniques used

Illustration 9. Large roof-mounted solar array

Illustration 10. Solar Photovoltaic installer with safety gear

to assess a site for a potential solar project. Some formal educational programs are available that teach basic site assessment including how to gauge the feasibility of solar generation, estimate costs, and determine which products to use.

Plumbers and electricians receive training through supervised apprenticeships administered by technical schools or community colleges. Apprenticeships usually consist of 4 or 5 years of paid on-the-job training and at least 144 hours of related classroom instruction per year. Most states require plumbers and electricians to be licensed. Licensing requirements vary, but it is common for states to require between 2 and 5 years of experience, followed by an examination that tests knowledge of trade and local codes. Applicants for apprenticeships must be at least 18 years old and in good physical condition. Drug tests may be required, and most apprenticeship programs ask that applicants have at least a high school diploma or equivalent.

Plumbers and electricians working on solar installation projects must also have specialized training on the systems that they will be installing, or they must work under the supervision of a qualified solar photovoltaic installer. Certification by the North American Board of Certified Energy Practitioners (NABCEP) is required for many jobs, particularly large commercial installations and residential installations.

Roofers typically have on-the-job training and may participate in 3-year apprenticeship program. Many roofers in the solar industry educate themselves through additional training, or they gain experience to become solar photovoltaic installers.

Wages

The following table shows BLS data for selected occupations in the Construction of Buildings industry group for May 2010. This industry group includes new residential and nonresidential construction and remodeling. BLS does not publish data for site assessors. The wages shown are median annual wages for the United States as a whole; wages vary by employer and location.

Selected occupations in the construction of buildings industry group	Median annual wages, 2010[1]
Electricians	$45,790
Plumbers, pipefitters, and steamfitters	50,550
Roofers	30,290

[1]The Occupational Employment Statistics data are available at **www.bls.gov/oes**. The data do not include benefits.

Occupations supporting the solar power industry

The advancement of the solar power industry has led to job creation in a number of other occupations as well. Many of these jobs do not concentrate on solar power, but they provide support to solar energy production and contribute to the industry as a whole. For instance, the solar power supply chain consists of many different manufacturers of varying sizes. Foundry workers are an important part of this supply chain; they cast metal, plastics, and composites out of raw materials into individual components for solar energy production.

Solar manufacturers need trained salespeople to sell their products to customers. Sales representatives, sales engineers, and sales managers are instrumental in matching a company's products to consumers' needs. They are responsible for making their products known and gen-

Illustration 11. Woman holding solar panel

erating interest in the products. Sales professionals may work directly for manufacturers, distributers, installers, or consulting services. A salesperson must stay abreast of new products and the changing needs of customers. They attend trade shows at which new products and technologies are showcased.

Conclusion

Clean energy such as solar power is expected to be a key piece of the growing "green economy," and jobs in solar power show great potential for new employment opportunities. Jobs are expected to grow in all the major sectors of the solar power industry: manufacturing, project development, construction, operation and maintenance, and installation. This growth in the solar power industry is evidenced by the rapid increase in solar capacity over the past several years, leading to the increased the demand for skilled workers. Jobs in this industry are located in many states and cover a wide variety of occupations. As solar technology evolves and new uses for solar power are discovered, occupations in the industry will continue to grow and develop.

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Notes

1. "Frequently Asked Questions about Solar Energy Technologies," SunShot Initiative (U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2011), **http://www1.eere.energy.gov/solar/sunshot/faqs.html.**

2. "U.S. Solar Industry, Year in Review 2009" (Solar Energy Industries Association, 2010), p. 2, **htttp://seia.org/galleries/default-file/2009%20Solar%20Industry%20Year%20in%20Review.pdf.**

3. "Electric Power Industry 2009: Year in Review," Electric Power Annual (U.S. Energy Information Administration, 2010), **http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html**.

4. The Bureau of Labor Statistics does not currently have employment data for the solar power industry. BLS has begun collecting green jobs data and it is expected to be available in 2012. For more information on the BLS green jobs initiatives please see **www.bls.gov/green.**

5. "National Solar Jobs Census 2010: A Review of the U.S. Solar Workforce" (The Solar Foundation, October 2010), p.4, **http://www.thesolarfoundation.org/sites/thesolarfoundation.org/files/Final%20TSF%20National%20Solar%20Jobs%20Census%202010%20Web%20Version.pdf.**

6. Ibid., p. 17.

7. "Large Solar Energy Projects" (California Energy Commission, 2010), **http://www.energy.ca.gov/siting/solar/index.html.**

8. "U.S. Solar Industry, Year in Review 2009," (Solar Energies Industries Association), p. 5.

9. "Photovoltaic Solar Resource: United States and Germany" (U.S. Department of Energy, National Renewable Energy Laboratory, 2008), **http://www.seia.org/galleries/default-file/PVMap_USandGermany.pdf.**