Solar Power

Electric power generated by using sunlight either to create electron flow in a photovoltaic cell or to heat a fluid that is used in the operation of an engine or turbine-generator.

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Electric energy can be generated from sunlight to meet electric energy requirements on a small scale, such as powering a single device, or on a larger scale, such as supplying a utility grid. Photovoltaic (PV) systems are modular, so they can easily be expanded or dismantled to meet a wide range of loads. Solar thermal technology, however, applies primarily to utility-scale operations.

Photovoltaic Power

A portion of the electromagnetic energy in sunlight can be captured by PV, or solar, cells and used to create electricity. PV cells are nonmechanical semiconductor devices, most commonly made of silicon, that produce direct current (dc) electricity. When the semiconductor material is exposed to sunlight, electrons are released within the silicon wafer and travel to the front surface, which receives these free electrons. When many electrons, each carrying a negative electric charge, travel toward the front of the cell, the charge imbalance between the cell's front and back surfaces creates a voltage potential. Because these surfaces are connected within a circuit, electricity flows as long as the sun is shining.

The fundamental component of a PV system is a solar cell. Groups of cells mounted on a plate and electrically connected make up a PV module. (In 1991, a typical commercially available module with a surface area of one-half square meter could generate approximately 50 watts, or W). Connected modules attached to a frame form a PV array (of any specified size), and arrays connected and electrically matched constitute a PV system.

The modular design of PV systems facilitates easy system expansion as more electric energy is required. Because the power produced by PV cells is dc electricity, it must be converted to alternating current (ac) electricity before it is introduced into the transmission and distribution (T&D) system. Inverters convert dc to ac. Utility-scale inverters are not yet available as compact units.

PV cells are a clean and quiet source of electric power in areas receiving strong sunlight. Clouds, rain, snow, and fog diffuse sunlight, or solar insolation, and limit the amount of electric energy that can be produced. Future PV systems may include storage capacity so that the electric energy supply is not interrupted at night or when solar insolation is low, but currently available storage methods are not yet cost effective.

Utility-scale PV power can help meet peak energy demand in areas where air conditioners draw a large amount of electric power during the hottest (and brightest) times of the year. PV systems also can supply electric energy in areas not served by power lines, such as remote residences. Other applications for PV technology include remote agricultural loads, communication devices, and cathodic protection systems for pipelines (which counter corrosive ground currents).

An in-depth field test and evaluation of utility-scale PV technology, the Photovoltaics for Utility Scale Applications (PVUSA) project being conducted in Davis, California, was founded and is managed by PG&E. Co-sponsors include the Department of Energy (DOE), the Electric Power Research Institute (EPRI), the California Energy Commission (CEC), and

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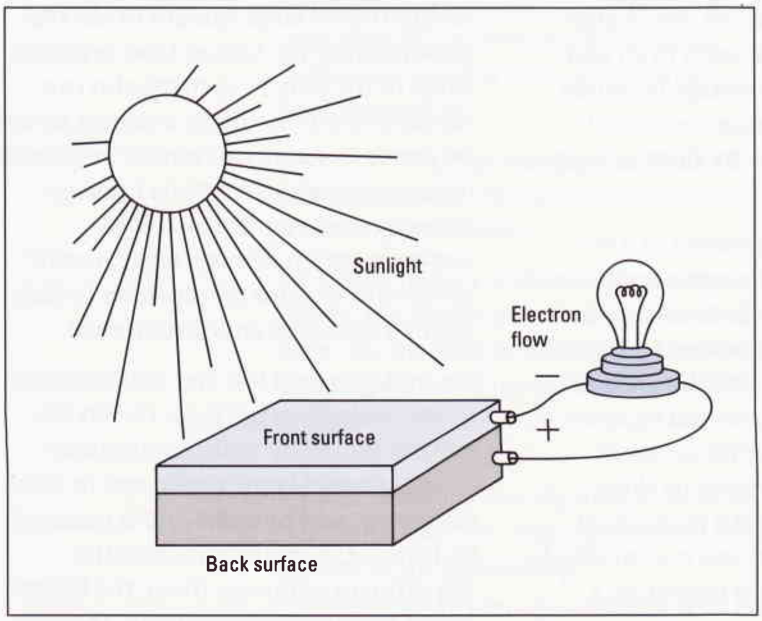
other utilities. The PVUSA project documents the performance, under realistic conditions, of a wide range of available PV modules and associated peripheral equipment. (Peripheral equipment includes inverters; PV trackers, which position PV modules throughout the day to face the sun directly; and controllers, which turn the PV system on and off, operate any trackers, and maximize the power efficiency of the system's output.)

PG&E also monitors electric energy output and equipment performance at Carrizo Solar Corporation's PV plant, located approximately 60 miles east of San Luis Obispo, California, at Carrizo Plains. This plant is currently the largest PV power plant in the world, with a capacity rating of nearly 5 megawatts (MW). PG&E purchases the plant's power output in accordance with provisions of the federal Public Utility Regulatory Policies Act (PURPA) of 1978, which defines solar power as a renewable resource and categorizes solar power plants as qualifying facilities (QFs).

As the photovoltaic (PV) cell absorbs sunlight, the semiconductor material (usually silicon) releases certain electrons, which migrate toward the cell's front surface. An electric potential is created between the two surfaces so that when they are joined by a conductor, electricity flows. PV cells create direct current (dc) electric energy, which is the same type of electric energy stored in a battery.

A Photovoltaic Cell



Solar Thermal Power Plants

Solar thermal systems concentrate solar heat into a "working fluid" that drives one of several types of engines or a conventional steam turbine-generator. (This heat can also be used in a commercial or industrial process.) The three primary types of plants are *solar thermal central receivers* (STCRs), *parabolic dishes*, and *parabolic troughs:*

☐ STCRs concentrate solar energy using hundreds or thousands of heliostats (mirrors) to focus solar radiation onto a tower-mounted central receiver vessel containing a working fluid such as molten salt, steam, or air. This heated fluid or gas is then used to drive a conventional turbine-generator.

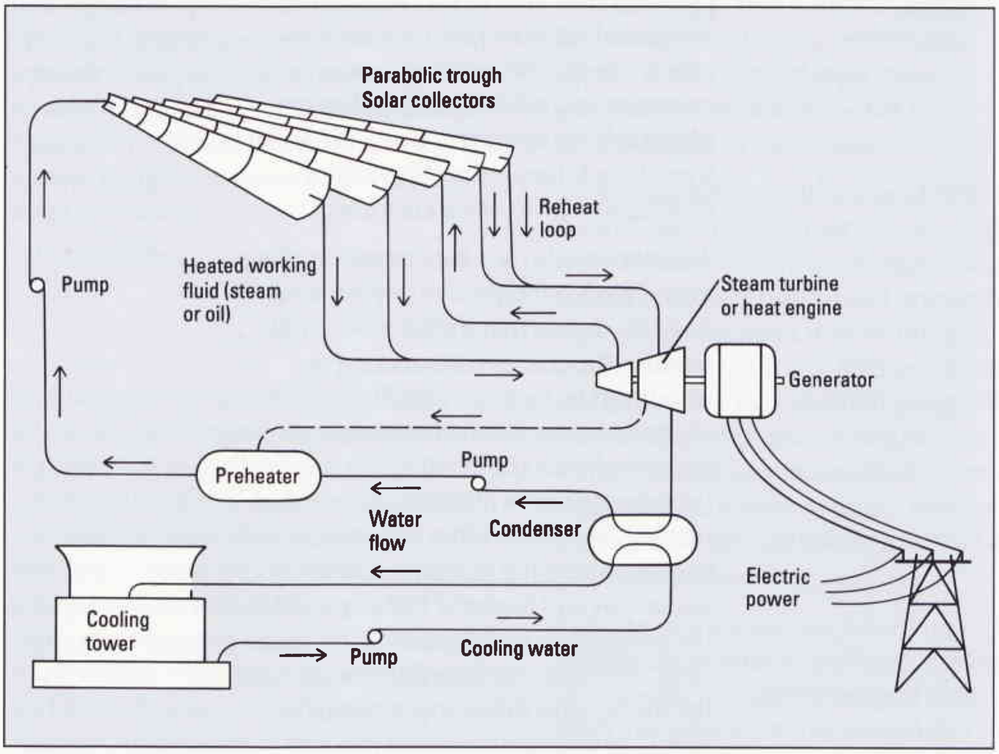
☐ Parabolic dish systems collect solar energy and focus it at the dish's focal point. Here, solar energy is absorbed as thermal energy and transferred to a working fluid for subsequent conversion into electric energy by either a heat engine mounted on the dish or a centrally located heat engine that receives heated fluid from several dishes.

☐ Parabolic troughs collect solar thermal energy and focus it along a focal line. A receiver tube along this focal line carries the heated working fluid to a heat engine, which converts thermal energy into electric energy.

Parabolic trough solar electric generating plants are currently the only commercially operating solar thermal electric systems. As of early 1992, 354 MW of generating capacity had been installed in Southern California. The plants are hybrid fossil fuel and solar systems that use oil as the working fluid and also use heaters fueled by natural gas when necessary, such as at night or during cloudy periods. (QF fuel-use standards limit the amount of electric energy generated using natural gas to 25 percent of the facility's annual electric output.)

PG&E collects solar insolation data at 15 sites within its service territory to assess resource availability patterns and to help predict solar power plant output in these areas. PG&E's research goals include helping to reduce the cost of viable solar power technologies by supporting development and demonstration of emerging commercial designs and identifying utility-compatible solar power system configurations.

Solar Trough Electric Power System



Parabolic troughs collect solar thermal energy and focus it along a focal line. A receiver tube along this focal line carries the heated working fluid (water or oil) to a steam turbine or heat engine, which converts thermal energy into electric energy. (If the working "fluid" is steam, a condenser loop cools the steam, creating water.)