Solar Energy

The amount of solar energy that the earth receives each day is many times greater than the total amount of all energy that people consume. Sunlight is composed of photons, or particles of solar energy. These photons contain varying amounts of energy that correspond to the different wavelengths of the solar spectrum.

Low-temperature solar thermal collectors absorb the sun's heat energy to heat water or to heat homes, offices, and other buildings. Concentrating solar energy technologies use mirrors to reflect and concentrate sunlight onto receivers that absorb solar energy and convert it to heat. We use this thermal energy for heating homes and buildings or to produce electricity with a steam turbine or a heat engine that drives a generator.

A photovoltaic (PV) cell, commonly called a solar cell, is a nonmechanical device that converts sunlight directly into electricity. Some PV cells can convert artificial light into electricity. A PV cell is made of semiconductor material. When photons strike a PV cell, they may reflect off the cell, pass through the cell, or be absorbed by the semiconductor material. Only the absorbed photons provide energy to generate electricity. When the semiconductor material absorbs enough sunlight (solar energy), electrons are dislodged from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to the dislodged, or free, electrons so that the electrons naturally migrate to the surface of the cell.

The movement of electrons, each carrying a negative charge, toward the front surface of the cell creates an imbalance of electrical charge between the cell's front and back surfaces. This imbalance, in turn, creates a voltage potential like the negative and positive terminals of a battery. Electrical conductors on the cell absorb the electrons. When the conductors are connected in an electrical circuit to an external load, such as a battery, electricity flows in the circuit. PV cells are electrically connected in a packaged, weather-tight PV module or panel. PV modules vary in size and in the amount of electricity they can produce. A PV array can be composed of two or hundreds of PV modules. The number of PV modules connected in a PV array determines the total amount of electricity that the array can generate.

Photovoltaic cells generate direct current (DC) electricity. This DC electricity can be used to charge batteries that, in turn, power devices that use direct current electricity. Nearly all electricity is supplied as alternating current (AC) in electricity transmission and distribution systems. Devices called inverters are used on PV modules or in arrays to convert the DC electricity to AC electricity.

PV modules and arrays can use tracking systems that move the modules to constantly face the sun, but these systems are expensive. Most PV systems have modules in a fixed position with the modules facing directly south (in the northern hemisphere—directly north in the southern hemisphere) and at an angle that optimizes the physical and economic performance of the system.

PV systems can supply electricity in locations where electricity distribution systems (power lines) do not exist, and they can also supply electricity to an electric power grid. Since 2004, most of the PV panels installed in the United States have been in grid-connected systems on homes, buildings, and central-station power facilities.

Solar thermal power generation systems collect and concentrate sunlight to produce the high temperature heat needed to generate electricity. All solar thermal power systems have solar energy collectors with two main components: reflectors (mirrors) that capture and focus sunlight onto a receiver. In most types of systems, a heat-transfer fluid is heated and circulated in the receiver and used to produce steam. The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity.

Solar thermal power systems may also have a thermal energy storage system component that allows the solar collector system to heat an energy storage system during the day, and the heat from the storage system is used to produce electricity in the evening or during cloudy weather. Solar thermal power plants may also be hybrid systems that use other fuels (usually natural gas) to supplement energy from the sun during periods of low solar radiation.

There are three main types of concentrating solar thermal power systems:

Linear concentrating systems collect the sun's energy using long, rectangular, curved (U-shaped) mirrors. The mirrors focus sunlight onto receivers (tubes) that run the length of the mirrors. The concentrated sunlight heats a fluid flowing through the tubes. The fluid is sent to a heat exchanger to boil water in a conventional steam-turbine generator to produce electricity.

A solar power tower system uses a large field of flat, sun-tracking mirrors called heliostats to reflect and concentrate sunlight onto a receiver on the top of a tower. Sunlight can be concentrated as much as 1,500 times. Some power towers use water as the heat-transfer fluid. The thermal energy-storage capability allows the system to produce electricity during cloudy weather or at night.

Solar dish/engine systems use a mirrored dish similar to a very large satellite dish. To reduce costs, the mirrored dish is usually composed of many smaller flat mirrors formed into a dish shape. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to an engine generator. This system uses the fluid heated by the receiver to move pistons and create mechanical power. The mechanical power runs a generator or alternator to produce electricity. The power-generating equipment used with a solar dish can be mounted at the focal point of the dish, making it well suited for remote locations, or the energy may be collected from a number of installations and converted into electricity at a central point.

Passive solar space heating happens when the sun shines through the windows of a building and warms the interior. Building designs that optimize passive solar heating usually have south-facing windows that allow the sun to shine on solar heat-absorbing walls or floors during the winter. Window overhangs or shades block the sun from entering the windows during the summer to keep the building cool.

Active solar heating systems use a collector and a fluid that absorbs solar radiation. Fans or pumps circulate air or heat-absorbing liquids through collectors and then transfer the heated fluid directly to a room or to a heat storage system. Active water heating systems usually have a tank for storing solar heated water.

Solar collectors are either nonconcentrating or concentrating

Nonconcentrating collectors—The collector area (the area that intercepts the solar radiation) is the same as the absorber area (the area absorbing the radiation). Flat-plate collectors are the most common type of nonconcentrating collectors and are used when temperatures lower than 200°F are sufficient. Solar systems for heating water or air usually have nonconcentrating collectors.

Concentrating collectors—The area intercepting the solar radiation is greater, sometimes hundreds of times greater, than the absorber area. The collector focuses or concentrates solar energy onto an absorber. The collector usually moves so that it maintains a high degree of concentration on the absorber. Solar thermal power plants use concentrating solar collector systems because they can produce high temperature heat.

Solar energy does not produce air or water pollution or greenhouse gases. However, using solar energy may have some indirect negative impacts on the environment. For example, some toxic materials and chemicals are used to make the photovoltaic (PV) cells that convert sunlight into electricity. Some solar thermal systems use potentially hazardous fluids to transfer heat. U.S. environmental laws regulate the use and disposal of these types of materials.

As with any type of power plant, large solar power plants can affect the environment near their locations. Clearing land for construction and the placement of the power plant may have long-term effects on habitat areas for native plants and animals. Some solar power plants may require water for cleaning solar collectors and concentrators or for cooling turbine generators. Using large volumes of ground water or surface water in some arid locations may affect the ecosystems that depend on these water resources. In addition, the beam of sunlight a solar power tower creates can kill birds and insects that fly into the beam.