

# Solar

## 2000 Facts at a Glance

Classification: Renewable Energy Source

Percent of energy produced in US:  $\approx 0.1$  (0.1 Q)

Percent of energy consumed in US:  $\approx 0.1$  (0.1 Q)

Major uses: \*light, \*heat, electricity

*\* Most of the solar energy we use for light and passive solar heating can't be measured and isn't included in these figures. Only harnessed solar energy is included in these figures.*

### What Is Solar Energy?

Solar energy is radiant energy that is produced by the sun. Every day the sun radiates, or sends out, an enormous amount of energy. The sun radiates more energy in one second than people have used since the beginning of time!

Where does the energy come from that constantly radiates from the sun? It comes from within the sun itself. Like other stars, the sun is a big ball of gases—mostly hydrogen and helium atoms. The hydrogen atoms in the sun's core combine to form helium and generate energy in a process called **nuclear fusion**.

During nuclear fusion, the sun's extremely high pressure and temperature cause hydrogen atoms to come apart and their nuclei (the central cores of the atoms) to fuse or combine. Four hydrogen nuclei fuse to become one helium atom. But the helium atom contains less mass than the four hydrogen atoms that fused. Some matter is lost during nuclear fusion. The lost matter is emitted into space as radiant energy.

It takes millions of years for the energy in the sun's core to make its way to the solar surface, and then just a little over eight minutes to travel the 93 million miles to earth. The solar energy travels to the earth at a speed of 186,000 miles per second, the speed of light.

Only a small portion of the energy radiated by the sun into space strikes the earth, one part in two billion. Yet this amount of energy is enormous. Every day enough energy strikes the United States to supply the nation's energy needs for one and a half years!

Where does all this energy go? About 15 percent of the sun's energy that hits the earth is reflected back into space. Another 30 percent is used to evaporate water, which, lifted into the atmosphere, produces rainfall. Solar energy also is absorbed by plants, the land, and the oceans. The rest could be used to supply our energy needs.

### History of Solar Energy

People have harnessed solar energy for centuries. As early as the 7th century B.C., people used simple magnifying glasses to concentrate the light of the sun into beams so hot they would cause wood to catch fire.

More than 100 years ago in France, a scientist used heat from a solar collector to make steam to drive a steam engine.

In the beginning of this century, scientists and engineers began researching ways to use solar energy in earnest. One important development was a remarkably efficient solar boiler invented by Charles Greeley Abbott, an American astrophysicist, in 1936.

The solar water heater gained popularity at this time in Florida, California, and the Southwest. The industry started in the early 1920s and was in full swing just before World War II. This growth lasted until the mid-1950s when low-cost natural gas became the primary fuel for heating American homes.

The public and world governments remained largely indifferent to the possibilities of solar energy until the oil shortages of the 1970s. Today, people use solar energy to heat buildings and water and to generate electricity.

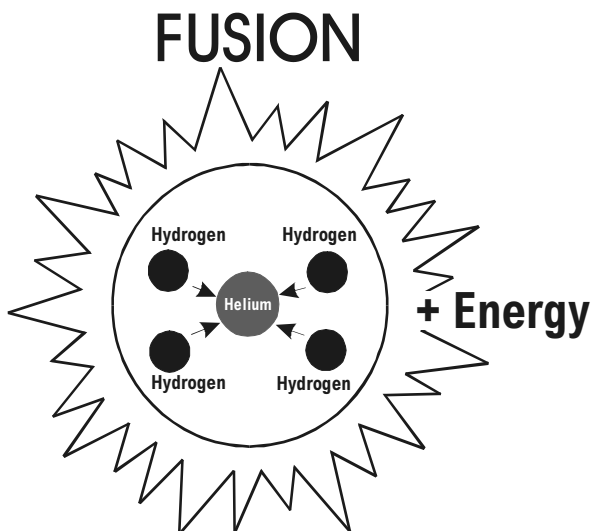
### Solar Collectors

Heating with solar energy is not as easy as you might think. Capturing sunlight and putting it to work is difficult because the solar energy that reaches the earth is spread out over a large area. The sun does not deliver that much energy to any one place at any one time.

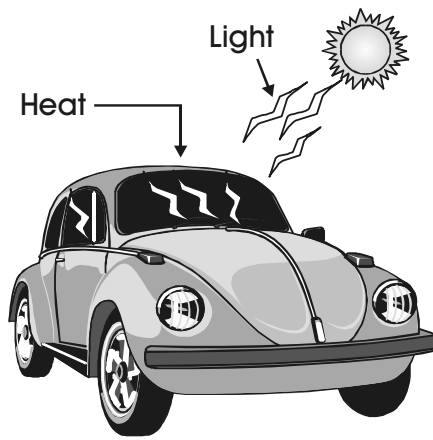
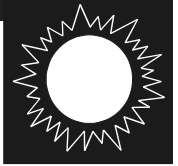
How much solar energy a place receives depends on several conditions. These include the time of day, the season of the year, the latitude of the area, and the clearness or cloudiness of the sky.

A solar collector is one way to collect heat from the sun. A closed car on a sunny day is like a solar collector. As sunlight passes through the car's glass windows, it is absorbed by the seat covers, walls, and floor of the car.

The light that is absorbed changes into heat. The car's glass windows let light in, but don't let all the heat out. This is also why



During a process called fusion, four hydrogen atoms combine to form one helium atom, with a loss of matter. This matter is emitted as radiant energy.



On a sunny day, a closed car becomes a solar collector. Light energy passes through the window glass, is absorbed by the car's interior and converted into heat energy. The heat energy becomes trapped inside.

greenhouses work so well and stay warm year-round. A greenhouse or solar collector:

- allows sunlight in through the glass (or plastic);
- absorbs the sunlight and changes it into heat;
- traps most of the heat inside.

## Solar Space Heating

Space heating means heating the space inside a building. Today many homes use solar energy for space heating. There are two general types of solar space heating systems: passive and active. A hybrid system is a mixture of the passive and active systems.

### Passive Solar Homes

In a passive solar home, the whole house operates as a solar collector. A passive house does not use any special mechanical equipment such as pipes, ducts, fans, or pumps to transfer the heat that the house collects on sunny days. Instead, a passive solar home relies on properly oriented windows. Since the sun shines from the south in North America, passive solar homes are built so that most of the windows face south. They have very few or no windows on the north side.

A passive solar home converts solar energy into heat just as a closed car does.

Sunlight passes through a home's windows and is absorbed in the walls and floors.

To control the amount of heat in a passive solar house, the doors and windows are closed or opened to keep heated air in or to let it out. At night, special heavy curtains or shades are pulled over the windows to keep the daytime heat inside the house.

In the summer, awnings or roof overhangs help to cool the house by shading the windows from the high summer sun.

Heating a house by warming the walls or floors is more comfortable than heating the air inside a house. It is not so drafty. And passive buildings are quiet, peaceful places to live. A passive solar home can get 50 to 80 percent of the heat it needs from the sun.

Many homeowners install equipment (such as fans to help circulate air) to get more out of their passive solar homes. When special equipment is added to a passive solar home, the result is called a hybrid system.

### Active Solar Homes

Unlike a passive solar home, an active solar home uses mechanical equipment, such as pumps and blowers, and an outside source of energy to help heat the house when solar energy is not enough.

Active solar systems use special solar collectors that look like boxes covered with glass. Dark-colored metal plates inside the boxes absorb the sunlight and change it into heat. (Black absorbs more sunlight than any other color.)

Air or a liquid flows through the collectors and is warmed by this heat. The warmed air or liquid is then distributed to the rest of the house just as it would be with an ordinary furnace system.

Solar collectors are usually placed high on roofs where they can collect the most sunlight. They are also put on the south side of the roof where no tall trees or tall buildings will shade them.

## Storing Solar Heat

The challenge confronting any solar heating system—whether passive, active, or hybrid—is heat storage. Solar heating systems must have some way to store the heat that is collected on sunny days to keep people warm at night or on cloudy days.

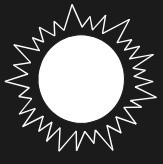
In passive solar homes, heat is stored by using dense interior materials that retain heat well—masonry, adobe, concrete, stone, or water. These materials absorb surplus heat and radiate it back into the room after dark. Some passive homes have walls up to one foot thick.

In active solar homes, heat may be stored in one of two ways—a large tank may store a hot liquid, or rock bins beneath a house may store hot air.

Houses with active or passive solar heating systems may also have furnaces, wood-burning stoves, or another heat source to provide heat in case there is a long period of cold or cloudy weather. This is called a backup system.

## Solar Water Heating

Solar energy is also used to heat water. Water heating is usually the second leading home energy expense, costing the average family over \$400 a year.



Depending on where you live, and how much hot water your family uses, a solar water heater can pay for itself in as little as five years. A well-maintained system can last 15-20 years, longer than a conventional water heater.

A solar water heater works in the same way as solar space heating. A solar collector is mounted on the roof, or in an area of direct sunlight. It collects sunlight and converts it to heat. When the collector becomes hot enough, a thermostat starts a pump. The pump circulates a fluid, called a heat transfer fluid, through the collector for heating.

The heated fluid then goes to a storage tank where it heats water. The hot water may then be piped to a faucet or showerhead. Most solar water heaters that operate in winter use a heat transfer fluid, similar to antifreeze, that will not freeze when the weather turns cold.

Today over 1.5 million homes in the U.S. use solar heaters to heat water for their homes or swimming pools.

Besides heating homes and water, solar energy also can be used to produce electricity. Two ways to generate electricity from solar energy are photovoltaics and solar thermal systems.

## Photovoltaic Cells

Photovoltaic comes from the words *photo* meaning light and *volt*, a measurement of electricity. Sometimes photovoltaic cells are called PV cells or solar cells for short. You are probably already familiar with solar cells. Solar-powered calculators, toys, and telephone call boxes all use solar cells to convert light into electricity.

Let's look at how a PV cell is made and how it produces electricity.

### Step 1

Pure silicon is used to form very thin wafers. In half of the wafers, a small amount of the element phosphorous is added. In the other wafers, a small amount of the element boron is added.

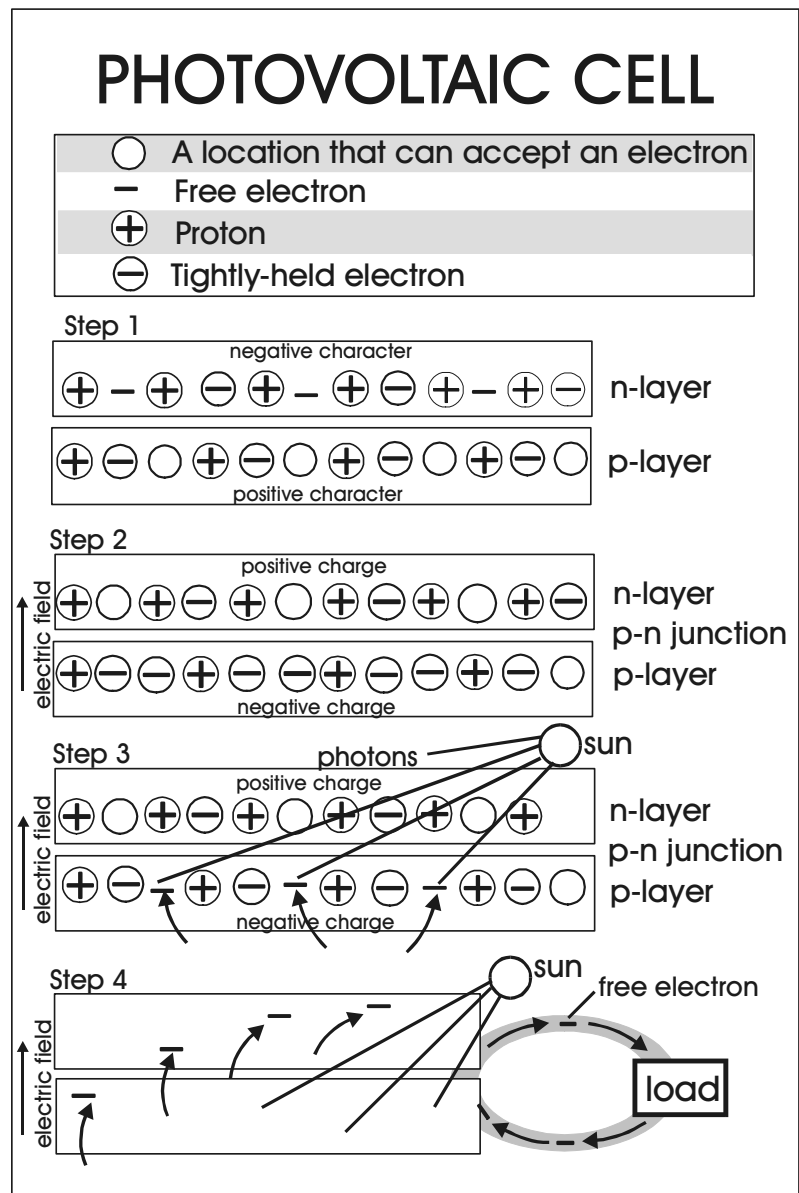
The phosphorous gives the wafer of silicon an excess of **free** electrons; therefore, it will have a negative character. This wafer with the phosphorous is called the **n-layer** (**n = negative**). The n-layer is not a charged wafer—it has an equal number of protons and electrons—but some of the electrons are not held tightly to the atoms in the wafer. They are free to move to different locations within the layer.

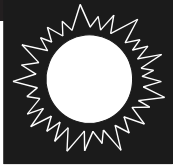
The boron gives its wafer of silicon a positive character, because it has a tendency to attract electrons. The layer has an equal number of protons and electrons; it has a positive character but not a positive charge. This wafer with boron is called the **p-layer** (**p=positive**).

### Step 2

When the two wafers are placed together, the free electrons from the n-layer are attracted to the p-layer. At the moment of contact between the two wafers, free electrons from the n-layer flow into the p-layer for a split second, then form a barrier to prevent more electrons from moving between layers. This contact point and barrier is called the **p-n junction**.

Once the layers have been joined, there is a negative charge in the p-layer section of the junction and a positive charge in the n-layer section of the junction. This imbalance in charge at the p-n junction produces an electric field between the p-layer and the n-layer.





### Step 3

If the PV cell is placed in the sun, photons of light energy strike the electrons in the p-n junction and energize them, knocking them free of their atoms. These electrons are attracted to the positive charge in the n-layer and repelled by the negative charge in the p-layer.

### Step 4

Now, let's attach a wire from the n-layer to the p-layer. As the free electrons are pushed into the n-layer, they repel each other. The wire provides a path for the electrons to get away. This flow of electrons is an electric current that can run a calculator or other electrical device as it travels from the n-layer to the p-layer.

Current PV cell technology is not very efficient. Today's PV cells convert only about 10 to 14 percent of the radiant energy into electrical energy. Fossil fuel plants, on the other hand, convert from 30 to 40 percent of their fuel's chemical energy into electrical energy.

The cost per kilowatt-hour to produce electricity from PV cells is currently three to four times as expensive as from conventional sources. However, PV cells make sense for many uses today, such as providing power in remote areas or other areas where electricity is difficult to provide. Scientists are researching ways to improve PV cell technology to make it more competitive with conventional sources.

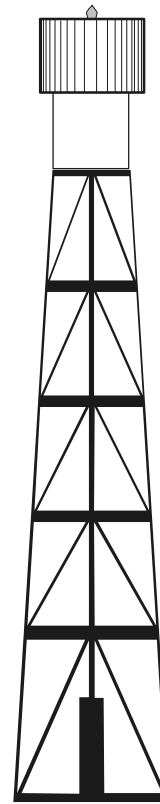
## Concentrated Solar Power

Like solar cells, concentrated solar power systems use solar energy to make electricity. Since the solar radiation that reaches the earth is so spread out and diluted, it must be concentrated to produce the high temperatures required to generate electricity. There are three types of technologies that use mirrors or other reflecting surfaces to concentrate the sun's energy up to 5,000 times its normal intensity.

**Parabolic troughs** use long reflecting troughs that focus the sunlight onto a pipe located at the focal line. A fluid circulating inside the pipe collects the energy and transfers it to a heat exchanger, which produces steam to drive a conventional turbine. The world's largest parabolic trough is located in the Mojave Desert in California. This plant has a total generating capacity of 354 megawatts, one-third the size of a large nuclear power plant.

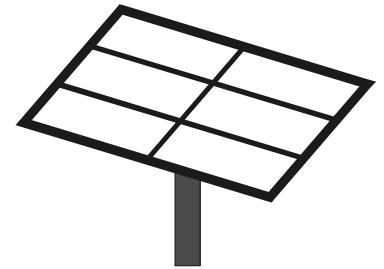
**Power towers** use a large field of rotating mirrors to track the sun and focus the sunlight onto a heat-receiving panel on top of a tall tower. The fluid in the panel collects the heat and either uses it to generate electricity or stores it for later use.

**Dish/engine systems** are like satellite dishes that concentrate sunlight rather than signals, with a heat engine located at the focal point to generate electricity. These generators are small mobile units that can be operated individually or in clusters, in urban and remote locations.



RECEIVER PANEL has fluid inside that collects heat.

ROTATING MIRRORS focus sunlight onto receiver panel.



## SOLAR POWER TOWER

Concentrated Solar Power (CSP) technologies require a continuous supply of strong sunlight, like that found in hot dry regions such as deserts. Developing countries with increasing electricity demand will probably be the first to use CSP technologies on a large scale.

## Solar Energy and the Environment

Using solar energy produces no air or water pollution, and it is a free and widely available energy source. Manufacturing the photovoltaic cells to harness that energy, however, consumes silicon and produces some waste products. In addition, large solar thermal farms can harm desert ecosystems if not properly managed. Most people agree, however, that solar energy, if it can be harnessed economically, is one of the most viable energy sources for the future.

