Renewable Energy

CHAPTER 18

READING WARM-UP

Before you read this chapter, take a few minutes to answer the following questions in your ***EcoLog.***

1. What is renewable energy? Do all forms of renewable energy have their origin in energy from the sun?
2. How might technology help us meet our energy needs in the future?

The power of the wind is one of the oldest energy resources used by humans. These Spanish windmills were built to grind grain hundreds of years ago. Today, wind energy is a rapidly growing industry.

SECTION 1

Renewable Energy Today

When someone mentions renewable energy, you may think of high-tech solar-powered cars, but life on Earth has always been powered by energy from the sun. **Renewable energy** is energy from sources that are constantly being formed. In addition to solar energy, renewable energy sources include wind energy, the power of moving water, and the Earth's heat.

Many governments plan to increase their use of renewable sources. For example, the European Union plans to produce 12 percent of their energy from renewable sources by 2010. Such a change will reduce the environmental problems caused by the use of nonrenewable energy. However, all sources of energy, including renewable sources, affect the environment.

Objectives

- List six forms of renewable energy, and compare their advantages and disadvantages.
- Describe the differences between passive solar heating, active solar heating, and photovoltaic energy.
- Describe the current state of wind energy technology.
- Explain the differences in biomass fuel use between developed and developing nations.
- Describe how hydroelectric energy, geothermal energy, and geothermal heat pumps work.

Key Terms

renewable energy
passive solar heating
active solar heating
biomass fuel
hydroelectric energy
geothermal energy

Solar Energy—Power from the Sun

What does the space station shown in **Figure 1** have in common with a plant? Both are powered by energy from the sun. The sun is a medium-sized star that radiates energy from nuclear fusion reactions in its core. Only a small fraction of the sun's energy reaches the Earth. However, this energy is enough to power the wind, plant growth, and the water cycle. So nearly all renewable energy comes directly or indirectly from the sun. You use direct solar energy every day. When the sun shines on a window and heats a room, the room is being heated by solar power. Solar energy can also be used indirectly to generate electricity in solar cells.

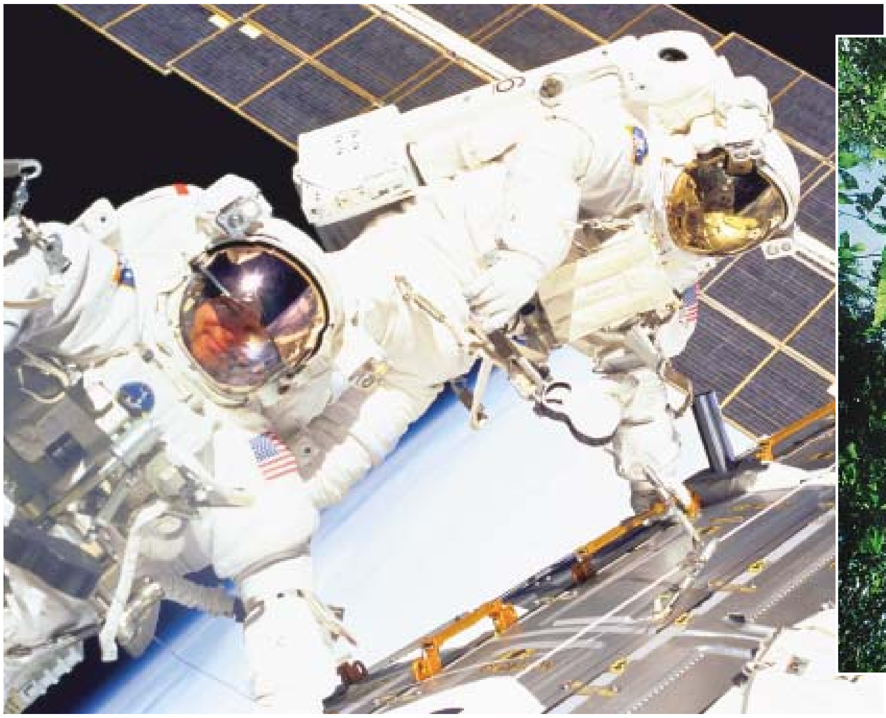


Figure 1 ▶ What does this plant have in common with a space station's solar panels? Both use energy from the sun.

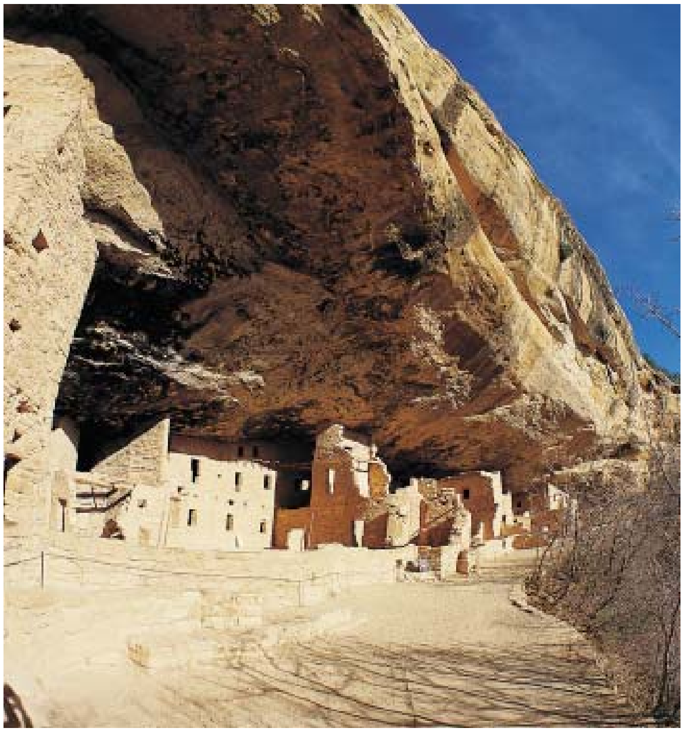


Figure 2 ▶ Seven hundred years ago, the Ancestral Puebloans, also called the Anasazi, lived in passive solar cliff dwellings in Mesa Verde, New Mexico.

Passive Solar Heating The cliff dwellings shown in **Figure 2** used passive solar heating, the simplest form of solar energy. **Passive solar heating** uses the sun's energy to heat something directly. In the Northern Hemisphere, south facing windows receive the most solar energy, so passive solar buildings have large windows that face south. Solar energy enters the windows and warms the house. At night, the heat is released slowly to help keep the house warm. Passive solar buildings must be well insulated with thick walls and floors in order to prevent heat loss.

Passive solar buildings are oriented according to the yearly movement of the sun. In summer, the sun's path is high in the sky and the overhang of the roof shades the building and keeps it cool. In winter, the sun's path is lower in the sky, so sunlight shines into the home and warms it. If there is reliable winter sunlight, an extremely efficient passive solar heating system can heat a house even in very cold weather without using any other source of energy. However, an average household could reduce its energy bills by using any of the passive solar features shown in **Figure 3.**

CASE STUDY

A Super-Efficient Home

Imagine a home located deep in the Rocky Mountains, where winter temperatures can plunge to –40°C (–40°F). The home has no furnace, yet it manages to stay comfortably warm even in the coldest weather. This home, built by energy experts Hunter and Amory Lovins in Snowmass, Colorado, is a prime example of a new generation of super-efficient structures.

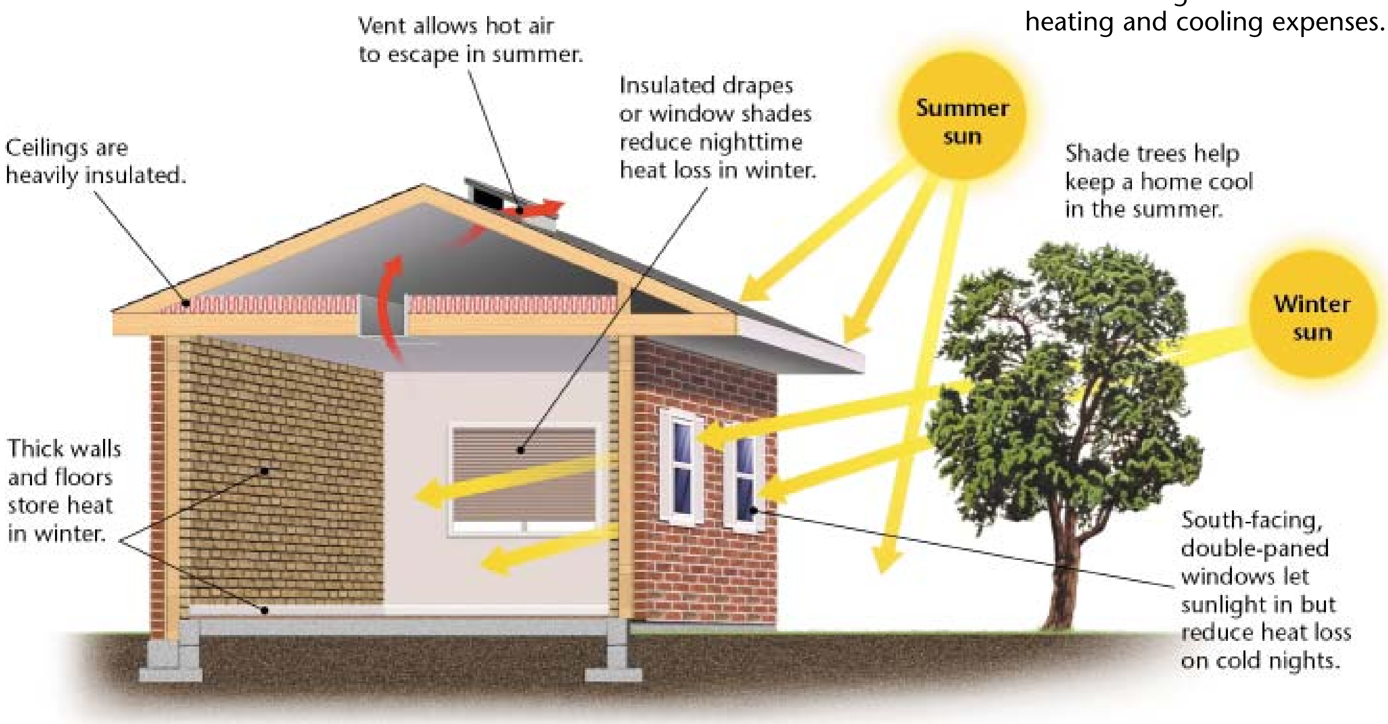
Efficiency without sacrifice was the goal in designing the Lovins's home, which also houses the Rocky Mountain Institute (RMI), an energy-research organization. The structure uses one-tenth the electricity and one-half the water of a similar-sized conventional building. The building cost more to build than a conventional structure, but that extra cost was recovered through energy savings in only three years.

Solar energy is the most important energy source for RMI. An abundance of south-facing windows lets in plenty of sunshine. As a result, little daytime lighting is required. Artificial lighting is provided by compact fluorescent lamps that draw only 18 W but provide as much light as standard 75 W incandescent bulbs. These lamps also last 10 to 13 times longer than ordinary bulbs. Motion sensors turn the lights off when a room is empty and turn them back on when someone enters the room.

Much of the building's electricity is provided by solar cells. If the building did not have equipment such as copiers and computers, it might not require any outside electricity at all. RMI staffer Owen Bailey said, "When the copier is not running, we actually send power back to the utility company."

Solar energy, plus the heat from appliances and human bodies, meets 90 percent of the heating needs. The other 10 percent is provided by two wood-burning stoves. The walls and roof of RMI are heavily insulated, greatly reducing heat loss. Also, the walls and windows are airtight, eliminating another common source of heat loss.

Figure 3 ▶ A passive solar home is designed to reduce heating and cooling expenses.



▶ **The Rocky Mountain Institute** uses the energy of the sun so efficiently that it can stay warm in the coldest Colorado winters.

During extended cloudy winter weather (with no solar heat input) the building loses only about 1°F per day. Nevertheless, the structure is well ventilated. It has specially designed air exchangers that vent stale air and warm the incoming fresh air.

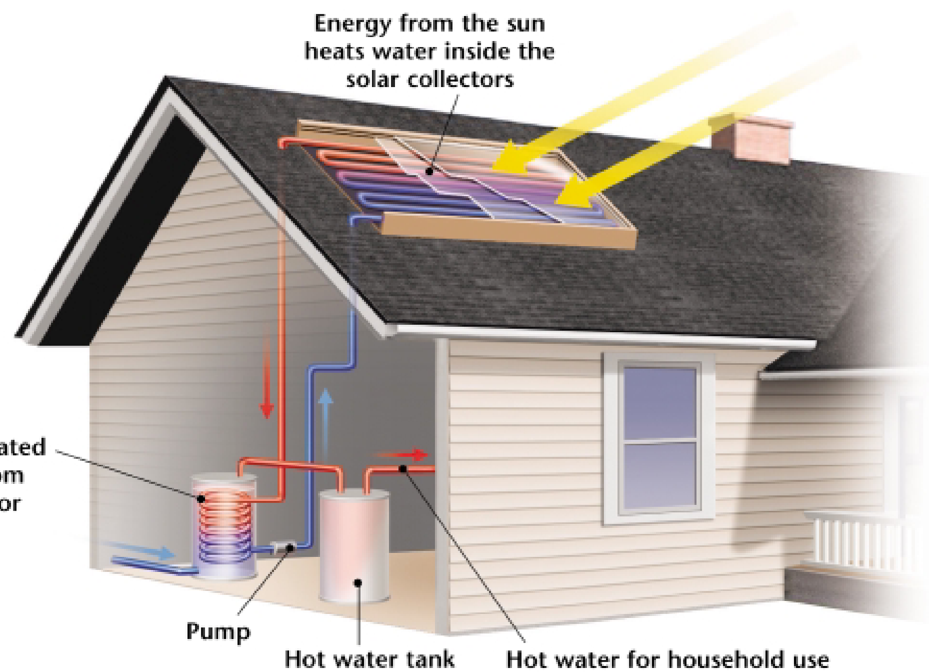
The RMI structure shows that conservation does not require discomfort. The building is comfortable and spacious. As Amory Lovins said, "The main thing that the Institute demonstrates is that conservation . . . doesn't mean freezing in the dark."

CRITICAL THINKING

1. Inferring Relationships Specially designed homes in Colorado are able to meet most of their heating needs using passive solar heating. But in parts of Canada and Alaska where winter weather can be similar to the weather in Colorado, solar-heating systems are often inadequate. Use what you know about latitude and solar radiation and write an explanation for this. WRITING SKILLS

2. Applying Ideas Currently, only about 1 percent of the homes built in this country have energy-efficient designs. What could be done to increase this percentage?

Figure 4 ▶ In a solar water heating system, a liquid is pumped through solar collectors. The heated liquid flows through a heat exchanger that transfers the energy to water, which is used in a household.



Active Solar Heating Energy from the sun can be gathered by collectors and used to heat water or to heat a building. This technology is known as **active solar heating.** More than 1 million homes in the United States use active solar energy to heat water. Solar collectors, usually mounted on a roof, capture the sun's energy, as shown in **Figure 4.** A liquid is heated by the sun as it flows through the solar collectors. The hot liquid is then pumped through a heat exchanger, which heats water for the building. About 8 percent of the energy used in the United States is used to heat water; therefore, active solar technology could save a lot of energy.

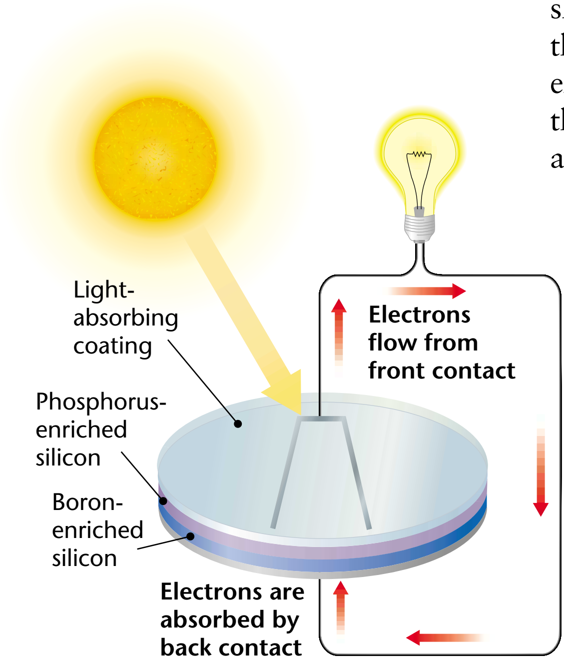
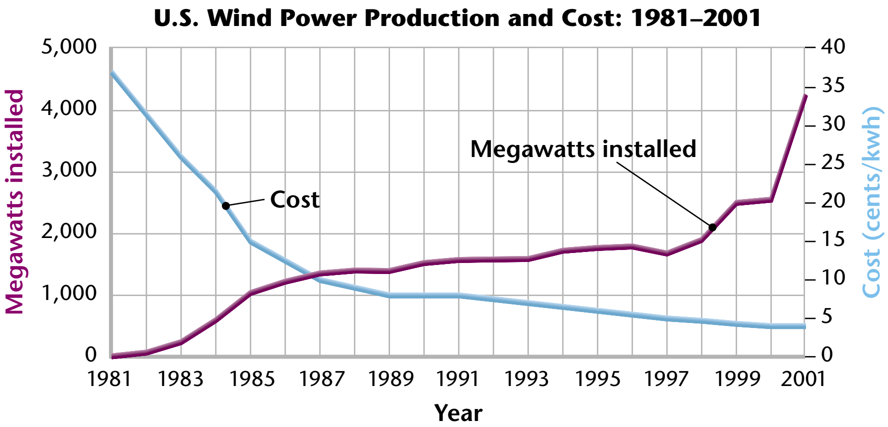


Figure 5 ▶ Sunlight falls on a semiconductor, causing it to release electrons. The electrons flow through a circuit that is completed when another semiconductor in the solar cell absorbs electrons and passes them on to the first semiconductor.

Photovoltaic Cells Solar cells, also called *photovoltaic* (FOHT oh vahl TAY ik) *cells,* convert the sun's energy into electricity, as shown in **Figure 5.** Solar cells were invented more than 120 years ago, and now they are used to power everything from calculators to space stations. Solar cells have no moving parts, and they run on nonpolluting power from the sun. So why don't solar cells meet all of our energy needs? A solar cell produces a very small electrical current. So meeting the electricity needs of a small city would require covering hundreds of acres with solar panels. Solar cells also require extended periods of sunshine to produce electricity. This energy is stored in batteries, which supply electricity when the sun is not shining.

Despite these limitations, energy production from solar cells has doubled every four years since 1985. Solar cells have become increasingly efficient and less expensive. Solar cells have great potential for use in developing countries, where energy consumption is minimal and electricity distribution networks are limited. Currently, solar cells provide energy for more than 1 million households in the developing world.



Source: American Wind Energy Association.

Figure 6 ▶ The cost of wind power has been steadily falling as wind turbines have become more efficient.

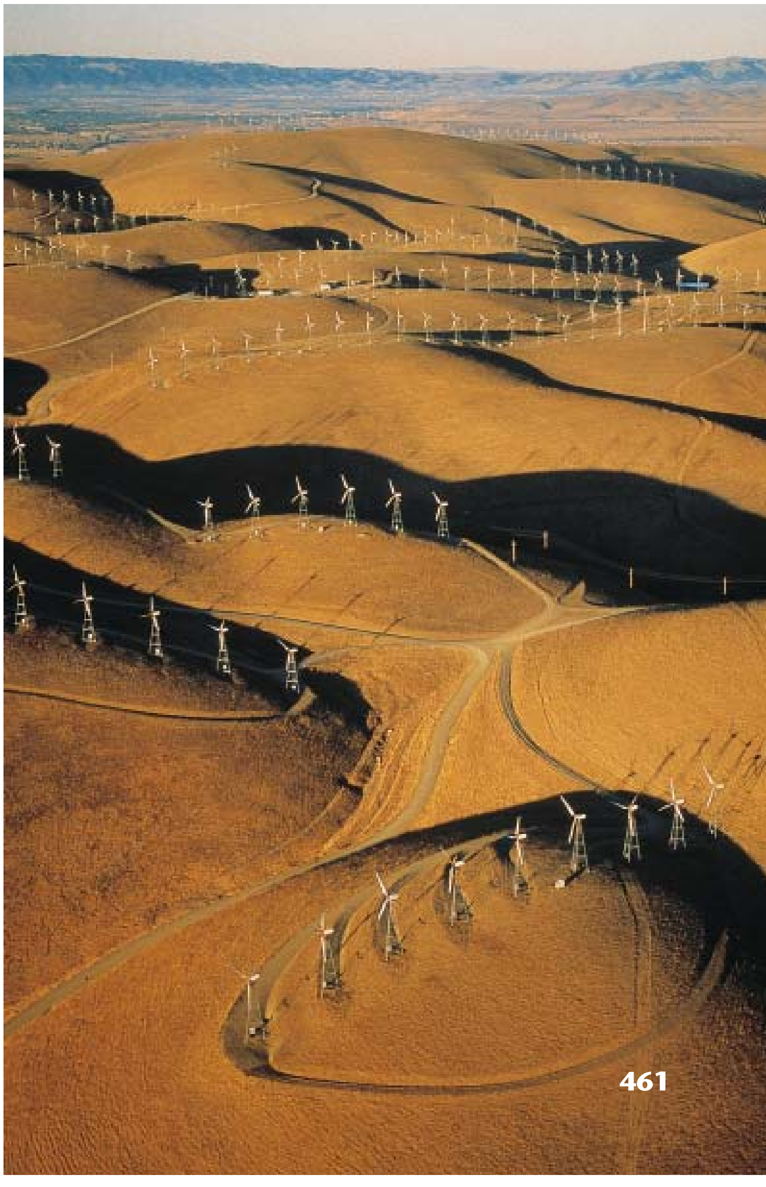
Wind Power—Cheap and Abundant

Energy from the sun warms the Earth's surface unevenly, which causes air masses to flow in the atmosphere. We experience the movement of these air masses as wind. Wind power, which converts the movement of wind into electric energy, is the fastest-growing energy source in the world. New wind turbines are cost effective and can be erected in three months. As a result, the cost of wind power has declined dramatically, as shown in **Figure 6.** The world production of electricity from wind power quadrupled between 1995 and 2000.

Wind Farms Large arrays of wind turbines, like the one shown in **Figure 7,** are called *wind farms*. In California, large wind farms supply electricity to 280,000 homes. In windy rural areas, small wind farms with 20 or fewer turbines are also becoming common. Because wind turbines take up little space, some farmers can add wind turbines to their land and still use the land for other purposes. Farmers can then sell the electricity they generate to the local utility.

An Underdeveloped Resource Scientists estimate that the windiest spots on Earth could generate more than ten times the energy used worldwide. Today, all of the large energy companies are developing plans to use more wind power. Wind experts foresee a time when prospectors will travel the world looking for potential wind-farm sites, just as geologists prospect for oil reserves today. However, one of the problems of wind energy is transporting electricity from rural areas where it is generated to urban centers where it is needed. In the future, the electricity may be used on the wind farm to produce hydrogen from water. The hydrogen could then be trucked or piped to cities for use as a fuel.

Figure 7 ▶ California wind farms, such as this one in Altamont Pass, generate more than enough electricity to light a city the size of San Francisco.



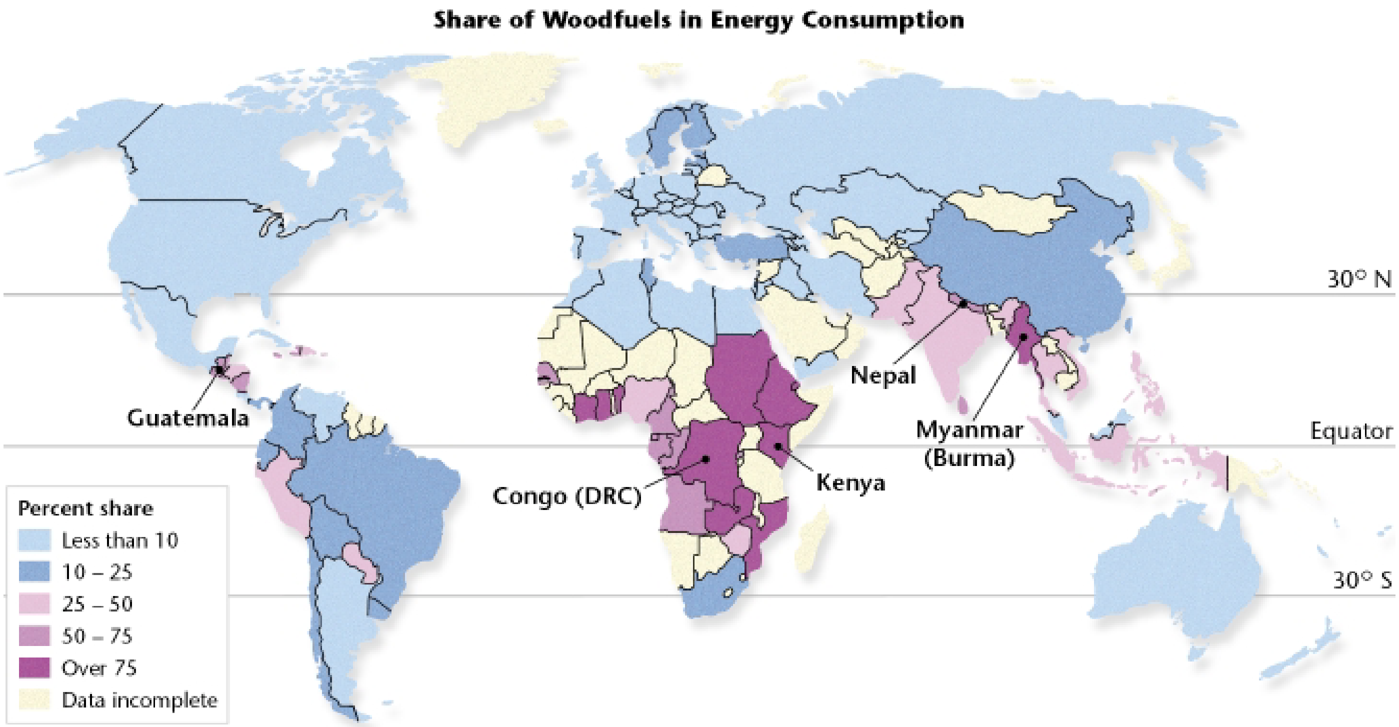


Figure 8 ▶ The consumption of wood as an energy source has increased by nearly 80 percent since 1960. In developing countries such as Nepal, Burma, Guatemala, Congo (DRC), and Kenya, the use of fuelwood places an enormous burden on local environments.

Biomass—Power from Living Things

Plant material, manure, and any other organic matter that is used as an energy source is called a **biomass fuel.** While fossil fuels are organic and can be thought of as biomass energy sources, fossil fuels are nonrenewable. Renewable biomass fuels, such as wood and dung, are major sources of energy in developing countries, as shown in **Figure 8.** More than half of all wood cut in the world is used as fuel for heating and cooking. Although wood is a renewable resource, if trees are cut down faster than they grow, the resulting habitat loss, deforestation, and soil erosion can be severe. In addition, harmful air pollution may result from burning wood and dung.

Methane When bacteria decompose organic wastes, one byproduct is methane gas. Methane can be burned to generate heat or electricity. In China, more than 6 million households use biogas digesters to ferment manure and produce gas used for heating and cooking. In the developed world, biomass that was once thought of as waste is being used for energy. In 2002, Britain's first dung-fired power station started to produce electricity. This power station uses the methane given off by cow manure as fuel. Similarly, some landfills in the United States generate electricity by using the methane from the decomposition of trash.

Alcohol Liquid fuels can also be derived from biomass. For example, ethanol, an alcohol, can be made by fermenting fruit or agricultural waste. In the United States, corn is a major source of ethanol. Cars and trucks can run on ethanol or *gasohol,* a blend of gasoline and ethanol. Gasohol produces less air pollution than fossil fuels do. For this reason, some U.S. states require the use of gasohol in vehicles as a way to reduce air pollution.

FIELD ACTIVITY

Biomass Survey Walk around your neighborhood, and list as many sources of biomass fuel as you can find. Are any of these (such as a pile of firewood) large enough to be used as fuel sources? What do you think the advantages and disadvantages of using biomass as a fuel in your area would be? Record your observations in your ***EcoLog.***

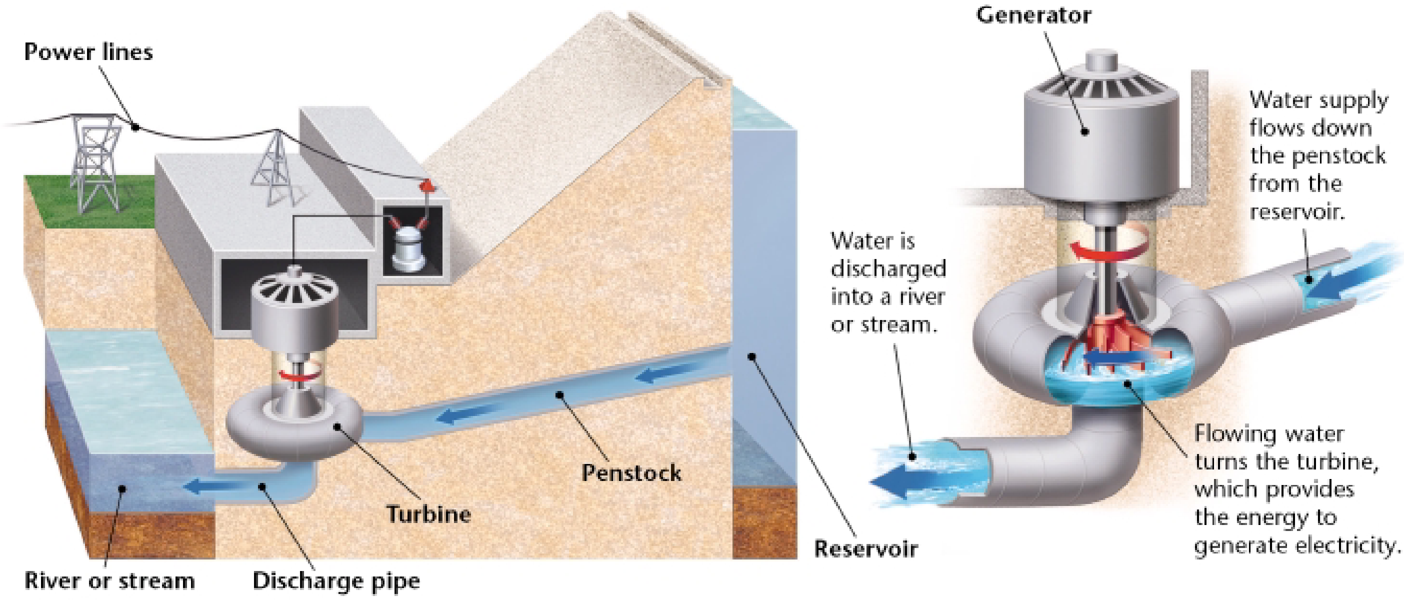


Figure 9 ▶ Hydroelectric dams convert the *potential energy,* or stored energy, of a reservoir into the *kinetic energy*, or moving energy, of a spinning turbine. The movement of the turbine is then used to generate electricity.

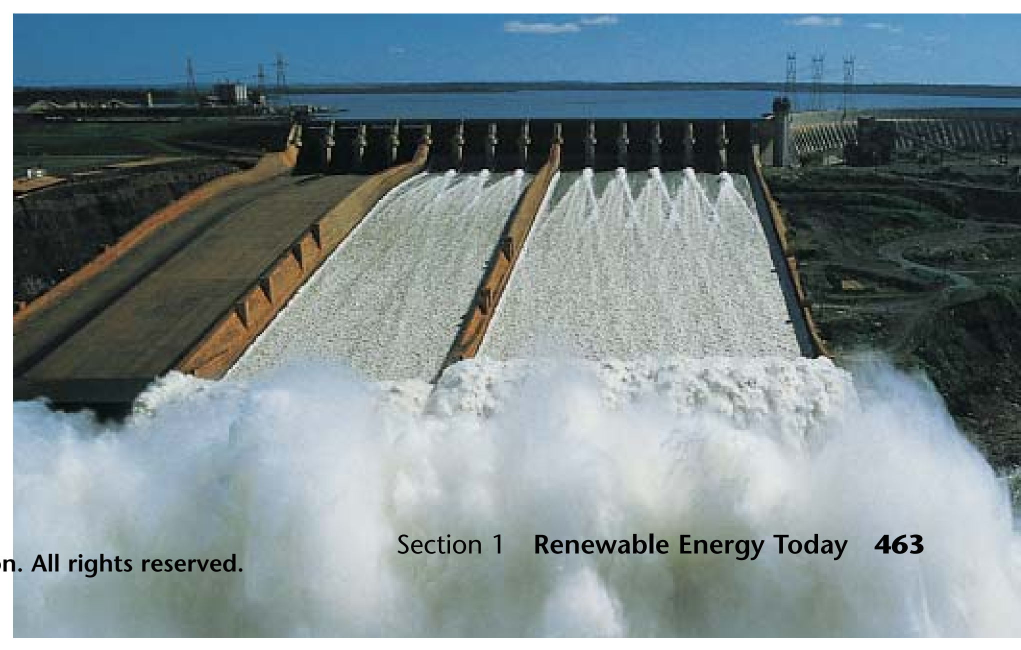
Hydroelectricity—Power from Moving Water

Energy from the sun causes water to evaporate, condense in the atmosphere, and fall back to the Earth's surface as rain. As rainwater flows across the land, the energy in its movement can be used to generate electricity. **Hydroelectric energy,** which is energy produced from moving water, is a renewable resource that accounts for about 20 percent of the world's electricity. The countries that lead the world in hydroelectric energy are, in decreasing order, Canada, the United States, Brazil, China, Russia, and Norway.

Figure 9 shows how a hydroelectric power plant works. Large hydroelectric power plants have a dam that is built across a river to hold back a reservoir of water. The water in the reservoir is released to turn a turbine, which generates electricity. The energy of this water is evident in **Figure 10,** which shows the spillway of the world's largest hydroelectric dam.

The Benefits of Hydroelectric Energy Although hydroelectric dams are expensive to build, they are relatively inexpensive to operate. Unlike fossil fuel plants, hydroelectric dams do not release air pollutants that cause acid precipitation. Hydroelectric dams also tend to last much longer than fossil fuel-powered plants. So the importance of hydroelectric energy is clear when you consider that nearly a quarter of the world's electricity is generated from this nonpolluting, renewable energy source. Dams also provide other benefits such as flood control and water for drinking, agriculture, industry, and recreation.

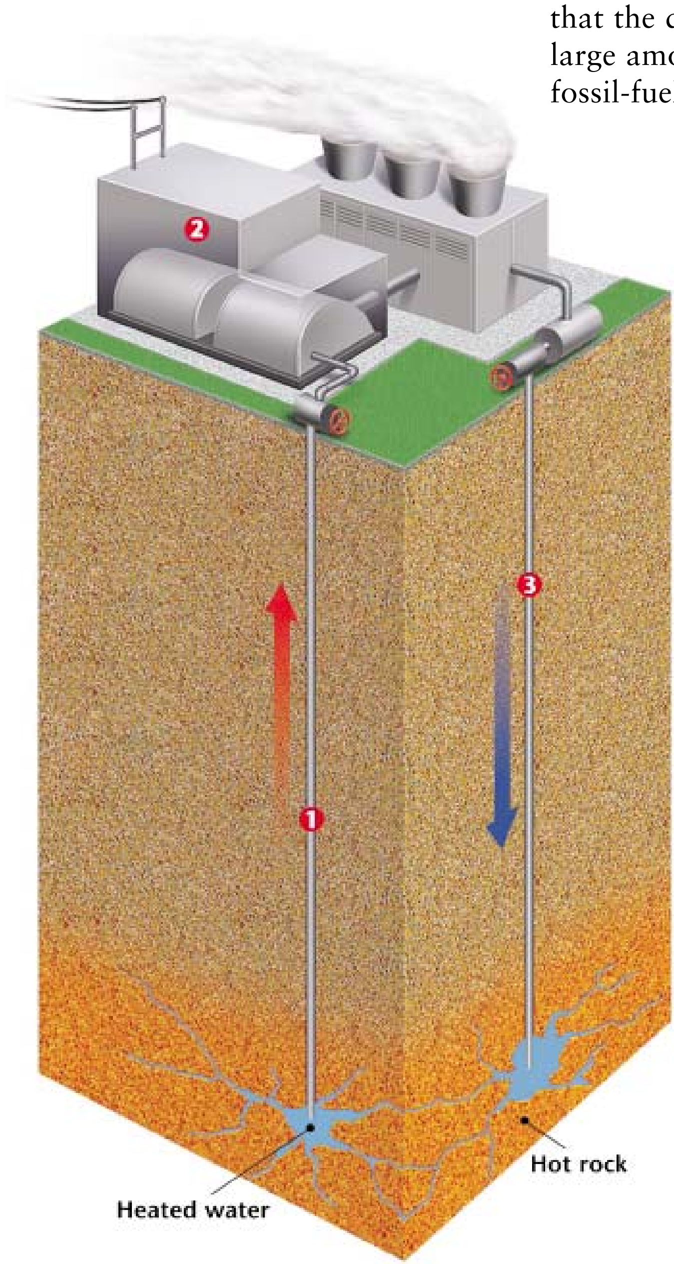
Figure 10 ▶ The Itaipu Dam in Paraguay supplies about 75 percent of the electricity used by Paraguay and 25 percent of the electricity used by Brazil.



Disadvantages of Hydroelectric Energy A dam changes a river's flow, which can have far-reaching consequences. A reservoir floods large areas of habitat above the dam. The water flow below the dam is reduced, which disrupts ecosystems downstream. For example, many of the salmon fisheries of the northwestern United States have been destroyed by dams that prevent the salmon from swimming upriver to spawn. When the land behind a dam is flooded, people are often displaced. An estimated 50 million people around the world have been displaced by dam projects. Dam failure can be another problem—if a dam bursts, people living in areas below the dam can be killed.

Dams can also affect the land below them. As a river slows down, the river deposits some of the sediment it carries. This fertile sediment builds up behind a dam instead of enriching the land farther down the river. As a result, farmland below a dam can become less productive. Recent research has also shown that the decay of plant matter trapped in reservoirs can release large amounts of greenhouse gases—sometimes more than a fossil-fuel powered plant.

Figure 11 ▶ Geothermal power plants generate electricity using the following steps: ❶ steam rises through a well; ❷ steam drives turbines, which generate electricity; ❸ leftover liquid water is pumped back into the hot rock.



Modern Trends In the United States, the era of large dam construction is probably over. But in developing countries, such as Brazil, India, and China, the construction of large dams continues. A modern trend is *micro-hydropower,* which is electricity produced in a small stream without having to build a big dam. The turbine may even float in the water, not blocking the river at all. Micro-hydropower is much cheaper than large hydroelectric dam projects, and it permits energy to be generated from small streams in remote areas.

Geothermal Energy—Power from the Earth

In some areas, deposits of water in the Earth's crust are heated by energy within the Earth. Such places are sources of **geothermal energy**—the energy from heat in the Earth's crust. As **Figure 11** shows, this heat can be used to generate electricity. Geothermal power plants pump heated water or steam from rock formations and use the water or steam to power a turbine that generates electricity. Usually the water is returned to the Earth's crust where it can be heated and used again.

The United States is the world's largest producer of geothermal energy. The world's largest geothermal power plant is The Geysers, in California, which produces electricity for about

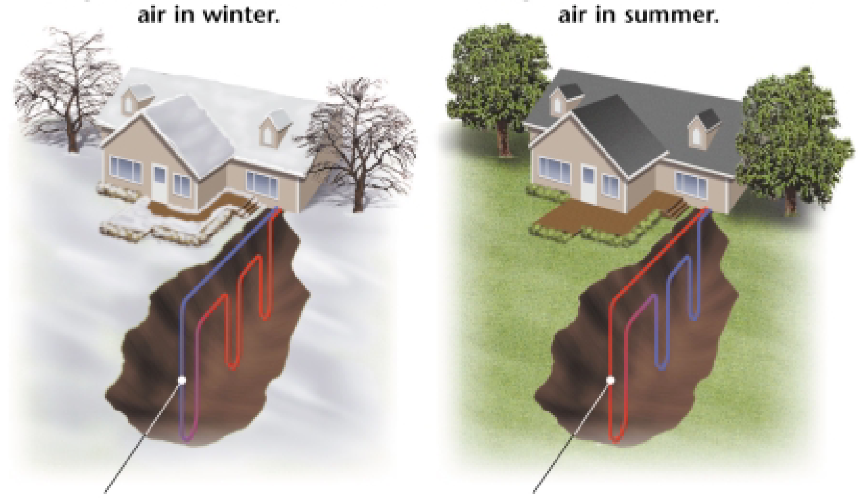


Figure 12 ▶ In the winter (left), the ground is warmer than the air is. A fluid is circulated underground to warm a house. In the summer (right), the ground is cooler than the air is, and the fluid is used to cool a house.

1.7 million households. Other countries that produce geothermal energy include the Philippines, Iceland, Japan, Mexico, Italy, and New Zealand. Although geothermal energy is considered a renewable resource, the water in geothermal formations must be managed carefully so that it is not depleted.

Geothermal Heat Pumps: Energy for Homes More than 600,000 homes in the United States are heated and cooled using geothermal heat pumps such as the one shown in **Figure 12.** Because the temperature of the ground is nearly constant year-round, a *geothermal heat pump* uses stable underground temperatures to warm and cool homes. A heat pump is simply a loop of piping that circulates a fluid underground. In warm summer months, the ground is cooler than the air, and the fluid is used to cool a home. In the winter, the ground is warmer than the air, and the fluid is used to warm the home.

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SECTION 1 Review

1. **List** six forms of renewable energy, and compare the advantages and disadvantages of each.
2. **Describe** the differences between passive solar heating, active solar heating, and photovoltaic energy.
3. **Describe** how hydroelectric energy, geothermal energy, and geothermal heat pumps work.
4. **Explain** whether all renewable energy sources have their origin in energy from the sun.

CRITICAL THINKING

5. **Making Decisions** Which renewable energy source would be best suited to your region? Write a paragraph that explains your reasoning. **WRITING SKILLS**
6. **Identifying Trends** Identify a modern trend in hydroelectric power and in wind energy.
7. **Analyzing Relationships** Write an explanation of the differences in biomass fuel use between developed and developing countries. **WRITING SKILLS**