Solar and Wind Energy

LESSON 3

Guiding Question: How can we rely on the sun and wind for power?

Knowledge and Skills

- Describe techniques for using solar energy to heat buildings and generate electricity.
- Analyze the benefits and costs of solar energy.
- Explain how wind energy can be used to produce electricity.
- Analyze the benefits and costs of wind energy.

Reading Strategy and Vocabulary

Reading Strategy Before you read, skim the lesson headings, illustrations, and vocabulary. Write down what you think this lesson will be about. Then, as you read, write down the things you read that are most surprising to you.

Vocabulary passive solar heating, active solar heating, flat-plate solar collector, photovoltaic (PV) cell, concentrating solar power (CSP), wind turbine, wind farm

WILLIAM KAMKWAMBA loves to read. When he was 14 years old, he needed electricity to power a light bulb so that he could read after sunset. William and his family live in a village in Malawi, a developing nation in Africa. Few people in rural Malawi have electricity.

In a nearby library, William found an old science textbook that described how wind energy could be used to generate electricity. So he decided to build a windmill that would do this. He constructed a slender wooden tower. On top of it he placed a generator he put together using plastic pipe, bicycle parts, and a few other things he found in trash piles.

His mother thought he was crazy, until one day he connected a light bulb to the generator. As the windmill's blades began to spin, light flickered in the bulb. Since that day, William has built other windmills that power light bulbs and radios and charge cell phones. Electricity from the windmills even pumps water for people in his village.

The wind energy that can run an electric generator ultimately comes from the sun, because the sun heats different parts of Earth unequally, and this unequal heating creates air currents. Both the sun and the wind provide energy that can be put to use.

William Kamkwamba and his windmill

MyEnvironmentalScience.com

18.3 LESSON PLAN PREVIEW

Differentiated Instruction Advanced students investigate how photovoltaic cells work.

Real World Students assess how feasible relying on solar energy would be for their city.

Inquiry Students use pinwheels as models to understand wind power.

18.3 RESOURCES

Scientific Method Lab, *Energy from Wind* • Map It Online • Lesson 18.3 Worksheets • Lesson 18.3 Assessment • Chapter 18 Overview Presentation

GUIDING QUESTION

FOCUS Ask students to make a T-chart. On one side of their T-charts, have students list advantages of using the sun and wind as power sources. On the other side, have students list disadvantages of these power sources. Call on students to share information from their T-charts with the class.

Harnessing Solar Energy

The sun's energy can be used to heat buildings and generate electricity.

The sun provides energy for almost all life processes on Earth, from the reproduction of tiny bacteria to the opening of flower buds. Every day, Earth receives a huge amount of energy from the sun. If we could harness one day's energy, it would power human consumption for 25 years. We may someday be able to use sunlight to meet many of our energy needs. However, we are still developing the technologies to do this.

When we use sunlight directly as a source of energy, without involving mechanical or electrical devices, we are using passive solar energy collection. This is the most common way that we harness solar energy. In contrast, active solar energy collection uses technology to focus, move, or store solar energy. The house in **Figure 13** uses both passive and active solar energy collection.

Passive Solar Heating We use passive solar energy to heat homes and buildings. **Passive solar heating** involves designing a building to collect, store, and distribute the sun's energy naturally. Greenhouses are designed to do this. Houses that are designed to use solar heating often have windows that face south and east to capture sunlight in winter. At night, window shades help keep the heat inside. Features such as these conserve energy and save energy costs.

Active Solar Heating An **active solar heating** system uses technology to collect, move, and store heat derived from the sun. One method of active solar heating uses devices called flat-plate solar collectors, which are sometimes called solar panels. A **flat-plate solar collector** generally consists of a black, heat-absorbing metal plate in a flat box with a glass cover. Sunlight passes through the glass, heating the metal plate. A long tube passes through the collector. Fluid in the tube absorbs heat from the metal plate. A pumping system circulates the fluid, transferring heat throughout the building. Heated water can be pumped to tanks to store the heat for later use. Flat-plate solar collectors are usually installed on rooftops, and they can be used to heat both water and air inside buildings.

Reading Checkpoint *How does a flat-plate solar collector work?*

ANSWERS

Reading Checkpoint In a flat-plate solar collector, sunlight heats a metal plate. Fluid in a tube absorbs heat from the metal plate. A pump circulates the heated fluid through a building.

Generating Electricity With Solar Energy Because passive and active solar heating methods supply heat to buildings, they can reduce the need for electricity and other forms of energy. However, neither passive nor active solar heating produces electricity. Two ways of using the sun's energy to generate electricity are photovoltaic cells and concentrating solar power.

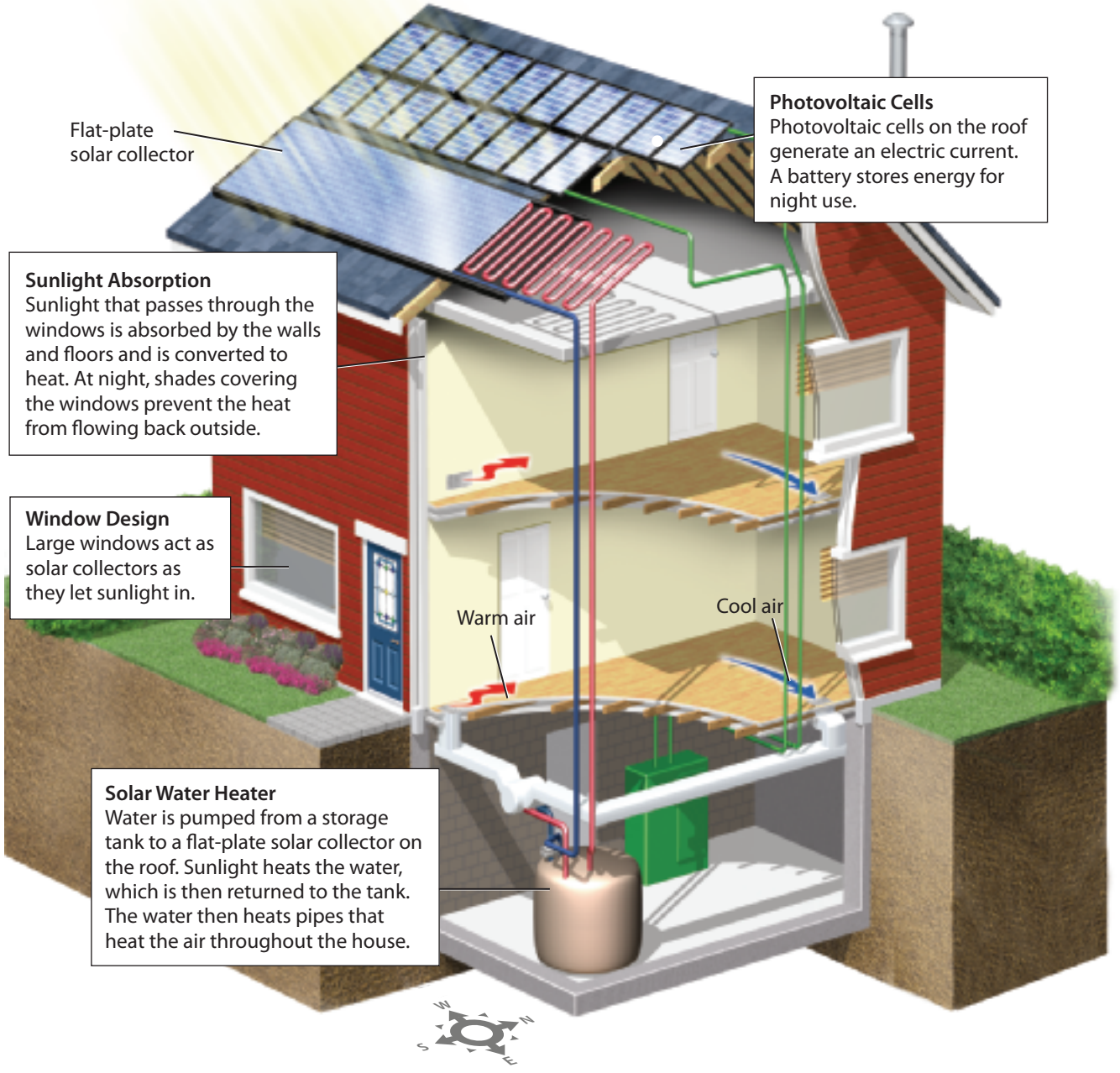
▶ ***Photovoltaic Cells*** In a **photovoltaic (PV) cell,** solar energy is converted directly into electricity. Photovoltaic cells contain two plates. The plates of a typical PV cell are made mainly of silicon. One of the plates is rich in electrons. When sunlight strikes this plate, it knocks some electrons loose. These electrons are attracted to the other plate. The flow of electrons from one plate to another creates an electric current.

Connect to the Central Case

FIGURE 13 Going Solar Any house can be adapted to use active and passive solar techniques for heating and for generating electricity. **Apply Concepts** In Germany, how can homeowners profit from extra electricity generated by photovoltaic cells?

ANSWERS

Figure 13 In Germany, extra electricity generated by photovoltaic cells can be sold back to electric utility companies.



PV cells have many uses. You may be familiar with small PV cells that power your watch or your calculator. Some power plants use PV cells to generate electricity for a wide area. In addition, individual households and businesses can use PV cells to obtain all or part of the electricity they use. On top of the roofs of homes and other buildings, PV cells are arranged in panels or contained in special roofing tiles.

Go Outside

Does the Temperature Change?

1. Obtain two clear, resealable plastic bags. Pour 250 mL of water into each bag.
2. Use a thermometer to measure the water temperature in each bag. Record the temperatures.
3. Put one bag in a shady place outdoors. Put the other bag in a sunny place.
4. Form a hypothesis about what will happen to the water temperature in each bag.
5. After 30 minutes, measure and record the water temperature in each bag.

Analyze and Conclude

1. **Observe** How did the water temperature change in each bag?
2. **Form a Hypothesis** How did the results correspond to your hypothesis?
3. **Apply Concepts** What energy conversion did you observe?
4. **Control Variables** Why was it important to measure the water temperature in both bags at the beginning of the experiment as well as the end?

ANSWERS

Go Outside For answers to the Go Outside activity, see page A–29 at the back of the book.

Reading Checkpoint A tall tower with a receiver on top. It uses sunlight, concentrated by many mirrors, to heat a fluid which produces steam, which is then used to generate electricity

▶ *Concentrating Solar Power (CSP)*

You probably think of a mirror as something you use to check your appearance before you go out. Mirrors can also be used to generate electricity through concentrating solar power. **Concentrating solar power (CSP)** is a technology that uses mirrors to focus sunlight in order to generate electricity. In one kind of CSP, hundreds of mirrors are positioned in a large area surrounding a tall tower, called a "power tower," as shown in **Figure 14.** The mirrors focus sunlight onto a receiver on top of the tower. The concentrated sun's rays heat a fluid in the receiver. The heated fluid is used to produce steam, and the steam turns the blades of a turbine, which powers a generator. Because this process uses steam, it is similar to the way a coal power plant produces electricity. However, the sun, not a coal fire, is the source of the heat that produces the steam.

Reading Checkpoint *What is a power tower?*

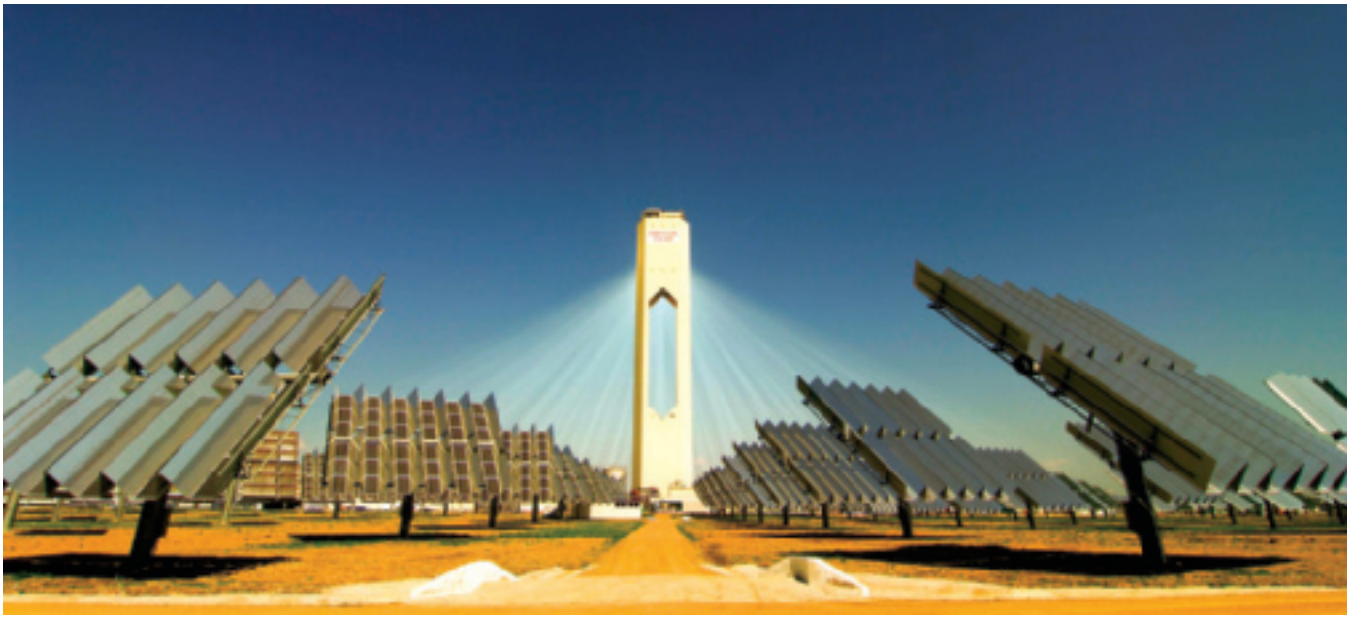


FIGURE 14 Concentrating Solar Power In this CSP facility in Spain, hundreds of mirrors focus sunlight toward the power tower to generate electricity.

FIGURE 15 Solar Power in Mongolia Far from any power plant, people in Mongolia can obtain electricity from photovoltaic cells.

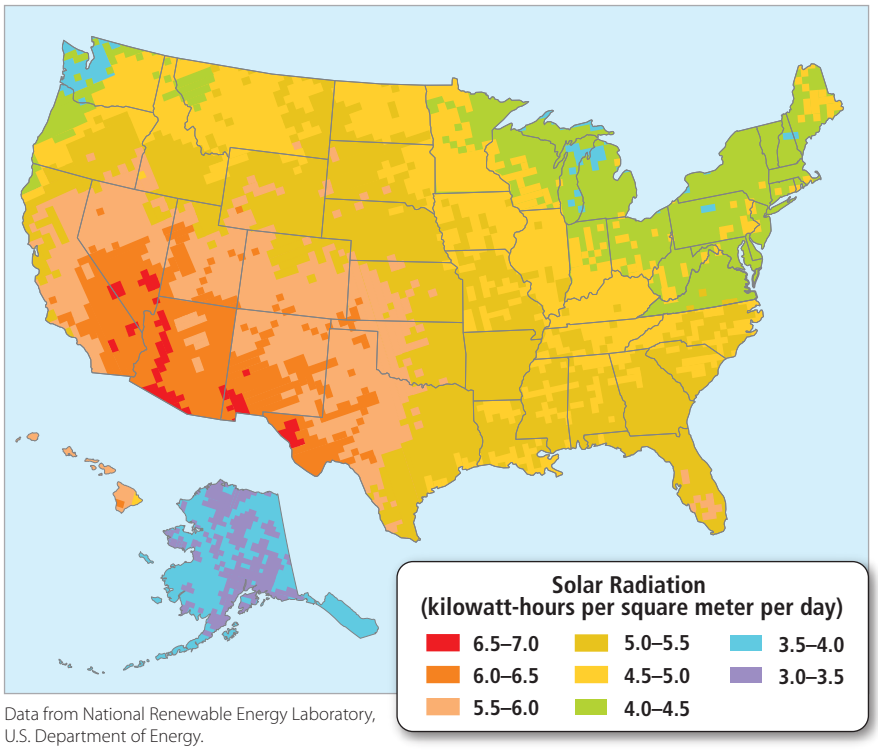
Benefits and Costs of Solar Power

Solar power has many benefits, such as its limitless supply, but it depends on weather and is currently expensive.

The sun will continue burning for another 4 to 5 billion years. Therefore, it is an inexhaustible energy source. In spite of this, solar energy contributes only a small part of today's energy production. However, solar energy worldwide has grown by 28 percent every year since 1971, a growth rate second only to that of wind power.

Benefits of Solar Power Solar energy has many benefits besides its endless source. PV cells and other solar technologies use no fuel. They are quiet and safe. Solar technology does not release greenhouse gases, and it does not pollute the air or water. Solar devices require little maintenance. An average unit can produce energy for 20–30 years. Homes, businesses, and isolated communities can use solar power to produce their own electricity. This production reduces dependence on power plants. Solar power is especially attractive in developing nations, because many of these nations have a lot of sun but few power plants.

In the developed world, most PV systems are connected to a regional electric grid. In Germany, owners of houses with PV systems can sell their excess solar electricity to the local power company. And in many states in the United States, consumers can lower their electric bill if they supply some electricity to their local electric company. Finally, the development of solar power is creating many new jobs.



Data from National Renewable Energy Laboratory, U.S. Department of Energy.

FIGURE 16 Sunlight in the United States Notice that some locations receive more sunlight than others. Therefore, harnessing solar energy is more profitable in some areas than in others.

BIG QUESTION

What are the potential uses and limitations of renewable energy sources?

Perspective Point out to students the information in the text that states "solar power is the most expensive way to produce electricity." Pose the following questions:

- Should people be forced to pay more for electricity in order to use renewable energy resources and reduce pollution?
- Should the government subsidize solar power to make it affordable?

Use these questions to launch a class discussion of the economic aspects of solar power.

ANSWERS

Reading Checkpoint The Southwest

Costs of Solar Power

The manufacturing of solar-energy devices creates some pollution. In addition, with the technology we now have, some regions are not sunny enough to provide much solar power. Seattle, for example, often has cloudy and rainy weather. Therefore, Seattle might find it difficult to depend on solar power.

Currently, solar equipment is expensive, so the investment cost for solar power is higher than that for fossil fuels. In fact, solar power is the most expensive way to produce electricity today. However, prices for solar equipment are falling fast. In addition, solar technologies are becoming more efficient. This increased efficiency is making it possible to produce energy for less money.

Reading Checkpoint *Look at **Figure 16.** Which part of the United States is most likely to benefit from solar energy?*

Windmills in the Netherlands

Harnessing Wind Power

Wind turbines convert wind's kinetic energy into electrical energy.

Indirectly, wind energy is a form of solar energy. The sun heats the atmosphere, and unequal heating of air masses causes winds to blow. People have used wind power for thousands of years. Windmills have ground grain into flour and pumped water to drain wetlands and irrigate crops. Even today, farms and ranches in parts of the United States use windmills to draw water up for thirsty cattle.

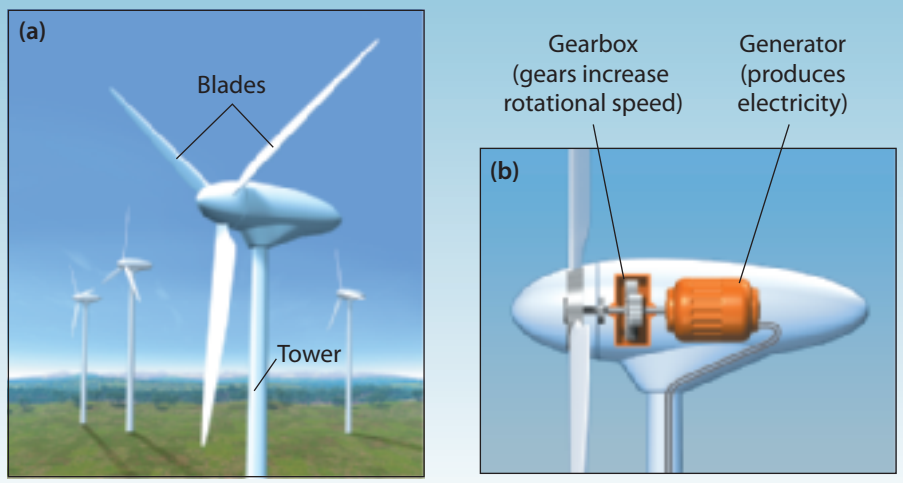
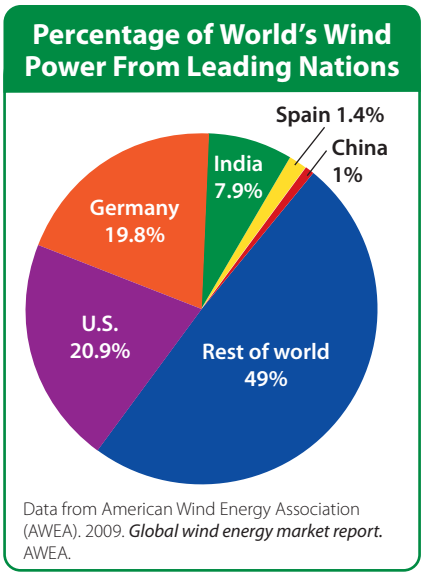


FIGURE 17 How a Wind Turbine Generates Electricity Wind spins the blades of a wind turbine **(a)**. The spinning motion is transferred to a gearbox **(b),** which in turn activates a generator.

Modern Wind Turbines Recall that electricity is often generated by using a turbine's rotating motion. A **wind turbine** is a device that converts the wind's kinetic energy, or energy of motion, into electrical energy. Wind blowing into a turbine turns blades that connect to a gearbox, as shown in **Figure 17.** The gearbox connects to a generator that produces electricity. Wind turbines are located on top of towers. Some of these towers are taller than a football field is long. Wind turbines are most often built in groups called **wind farms.** The world's largest wind farms contain hundreds of turbines **(Figure 18).**

Offshore Wind Turbines Average wind speeds are approximately 20 percent greater over water than over land. For this and other reasons, offshore wind turbines are becoming more common. Costs to erect and maintain wind turbines in water are higher than for wind turbines located on land. However, the stronger winds produce more power and may make offshore wind turbines more profitable than wind turbines on land.

FIGURE 18 A Wind Farm This wind farm supplies electricity to an area in California.



Connect to the Central Case

FIGURE 19 Where Wind Energy Is Significant The graph shows the percentage of world wind power supplied by various nations. **Interpret Graphs** What percentage of the world's wind power does Germany supply?

Benefits and Costs of Wind Power

Wind power is nonpolluting and efficient, but its supply is unpredictable and it may damage the landscape and wildlife.

The graph in **Figure 19** shows that five nations account for about half of the world's wind power output. Like other forms of energy that we use, wind power has both benefits and costs. Some of these advantages and disadvantages are described below.

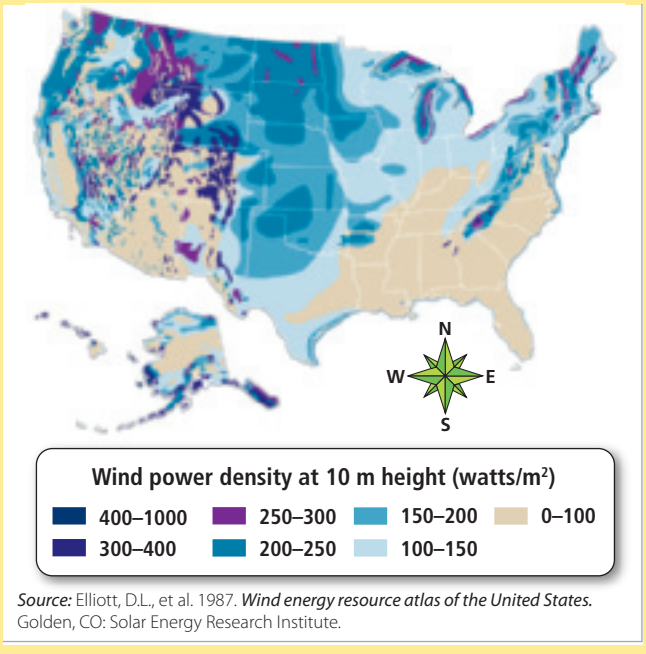
Benefits of Wind Power Like solar power, wind power does not cause pollution. The U.S. Environmental Protection Agency (EPA) has calculated that during a year, a 1-megawatt wind turbine prevents the release of more than 1500 tons (1361 metric tons) of carbon dioxide, 6.5 tons (5.9 metric tons) of sulfur dioxide, 3.2 tons (2.9 metric tons) of nitrogen oxides, and 60 pounds (27.2 kilograms) of mercury. Under the best conditions, wind power appears to be highly efficient. One study found that wind turbines produce 23 times more energy than they use. Wind-turbine development can range from one or two turbines to huge wind farms. Small-scale development can help make local areas more self-sufficient, just as small-scale solar energy can. Startup costs of wind farms generally are higher than those of plants powered by fossil fuels, but wind farms are less expensive once they are up and running.

Map it

Wind Patterns

The map shows how wind conditions compare in different parts of the United States. Use the map to answer the following questions.

1. **Interpret Maps** In general, which part of the United States—the eastern part or the western part—has winds with the highest density?
2. **Interpret Maps** Find your state on the map. Do you think your state could obtain a lot of its energy from wind? Explain your answer.
3. **Infer** Do you think the southeastern part of the United States has many wind farms? Explain your answer.
4. **Infer** On the basis of the circle graph in **Figure 19,** what can you infer about the state of the wind-energy industry in the United States?



Source: Elliott, D.L., et al. 1987. *Wind energy resource atlas of the United States.* Golden, CO: Solar Energy Research Institute.

FIGURE 20 Wind Energy Job
Wind power provides work for many people. Here, a technician works atop a wind turbine high above the ground.

Costs of Wind Power We have no control over when wind will occur. This unpredictability is a major limitation of wind as an electricity source. Some areas are windier than others, and wind power is not a good choice in places with little wind. The wind-power industry has located much of its generating capacity in states with high wind speeds, but these areas are often far from the large population centers that need the electricity.

Other factors besides unpredictability can prevent the use of wind power. For example, when wind farms are proposed near communities, the people living in the area often oppose them. Many people think that wind turbines clutter the landscape and are too noisy. In addition, birds and bats can be killed when they fly into the rotating blades on wind towers. This is a negative effect scientists are not certain about how to handle. The best strategy may be to avoid constructing wind farms in certain places, such as along bird and bat migration routes.

ANSWERS

Figure 19 19.8 percent

Map It

1. The western part
2. Answers will vary.
3. No; the southeastern part of the U.S. probably does not have many wind farms because it has relatively low wind power density.
4. The wind energy industry in the United States seems to be well established as it is one of the top contributors to the world's wind power.

Lesson 3 Assessment For answers to the Lesson 3 Assessment, see page A–29 at the back of the book.

LESSON 3 Assessment

1. **Compare and Contrast** What is the main difference between passive solar heating and active solar heating?
2. **Identify** List four benefits of solar power.
3. **Explain** Explain how a wind turbine generates electricity.
4. **Identify** List two benefits and two costs of wind power.
5. **THINK IT *THROUGH*** You work for a company that develops wind farms. Officials in a major city have asked you to evaluate the possibility of constructing a wind farm on a ridge top among the city's suburbs. What questions would you want answered before deciding whether or not to recommend the site?