Chapter 12

Energy and Material Resources

CALIFORNIA Standards Preview

S 6.3 Heat moves in a predictable flow from warmer objects to cooler objects until all the objects are at the same temperature. As a basis for understanding this concept:

a. Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.

b. Students know that when fuel is consumed, most of the energy released becomes heat energy.

S 6.6 Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation. As a basis for understanding this concept:

a. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

b. Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.

c. Students know the natural origin of the materials used to make common objects.

These California wind turbines use the energy of the wind to generate electricity. ▶

Video Preview
Discovery Channel School
Energy Resources

Focus on the
BIG Idea

S 6.6.b

What are the advantages and disadvantages of various energy resources?

Check What You Know

Suppose you are sailing on a boat across a lake or bay. What is the main source of energy that causes the sailboat to move? Do you think that this energy resource could be used for other purposes? Explain.

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Prefixes

A prefix is a word part that is added at the beginning of a word to change its meaning. For example, *re-* meaning "again" is a prefix that is frequently used in science. In the word *rewrite*, the prefix *re-* is added to the word *write* to form *rewrite*, meaning "to write again."

re-	+	**write**	=	**rewrite**
again		write		write again

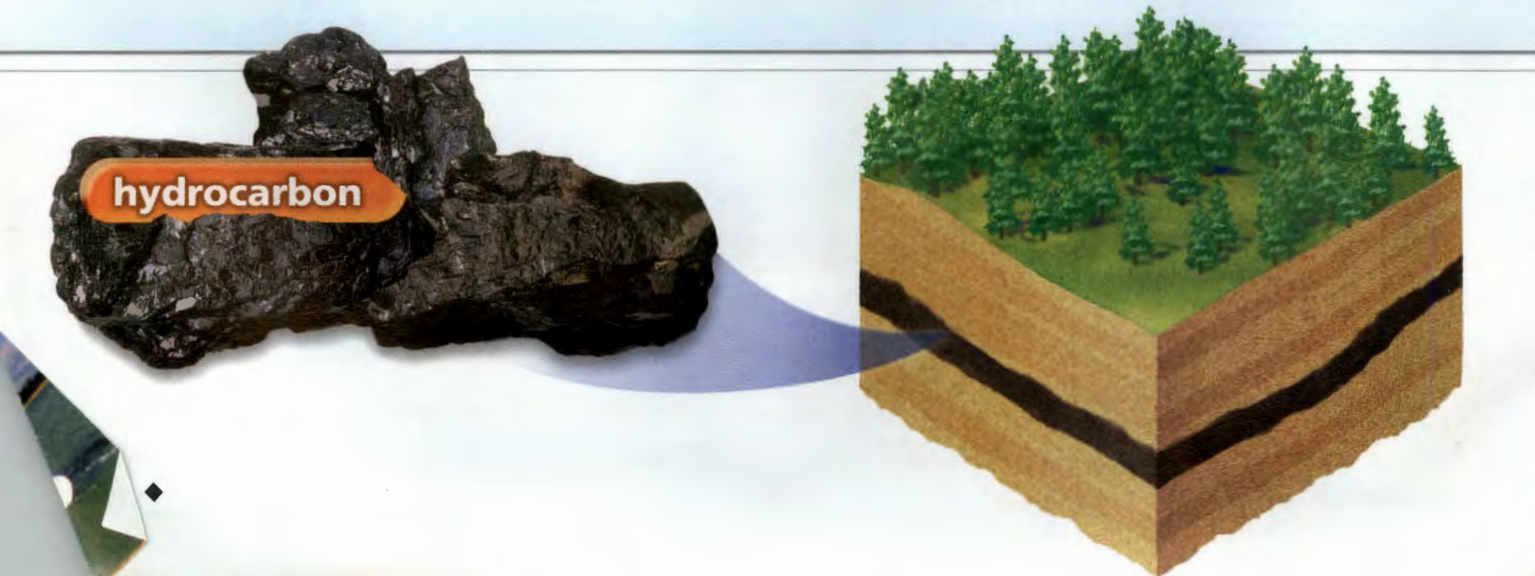
Use the prefixes below to help you learn the key terms.

Prefix	Meaning	Key Terms
bio-	Life	Biomass, biodegradable
com-	With, together	Combustion
con-	With, together	Conservation
hydro-	Water	Hydrocarbon, hydroelectric
re-	Again, back	Recycling

Apply It!

Review the prefixes above. Then predict what the word *recycling* means using what you know about the prefix *re-*. After reading the chapter, revise your definition as needed.

Look for these prefixes as you read the chapter.



Chapter 12 Vocabulary

Section 1 (page 478)
fuel
energy transformation
combustion
fossil fuel
hydrocarbon
petroleum
refinery
petrochemical

Section 2 (page 485)
solar energy
hydroelectric power
biomass fuel
gasohol
geothermal energy
tide

Section 3 (page 494)
nucleus
nuclear fission
reactor vessel
fuel rod
control rod
meltdown
nuclear fusion

Section 4 (page 499)
efficiency
insulation
energy conservation

Section 5 (page 506)
municipal solid waste
incineration
leachate
sanitary landfill
recycling
biodegradable
composting

Interactive Textbook
Build Science Vocabulary *Online*
Visit: PHSchool.com
Web Code: cwj-4120

How to Read Science

Reading Skill

Compare and Contrast

Science texts often make comparisons. When you compare and contrast, you examine the similarities and differences between things. You can compare and contrast by using a table.

Follow these steps to set up a compare/contrast table.

- List the characteristics or features to be compared across the top of the table.
- List the items to be compared in the left column.
- Complete the table by filling in information about each characteristic or feature.

In this chapter, you will learn about coal, oil, and natural gas—three major sources of energy. Look at the compare/contrast table. Complete the table after reading Section 1.

Energy Type	Advantages	Disadvantages
Coal	Low cost, plentiful	
Oil		Nonrenewable, mostly imported
Natural gas		

Apply It!

Review the compare/contrast table and answer the questions.

1. What energy resources are being compared in the table?
2. What characteristics are being compared?
3. In what column would you place additional energy types to be compared?

After reading Section 2, create a table comparing solar energy, hydroelectric power, and wind power. After reading Section 3, create a table comparing nuclear fission and nuclear fusion.

Lab zone

Standards **Investigation**

S 6.6.a, 6.7.d

Energy Audit

How much energy does it take to keep your school running? In this chapter's investigation, you will work in a group to study energy use in your school.

Your Goal

To report on one type of energy use in your school and make suggestions for saving energy

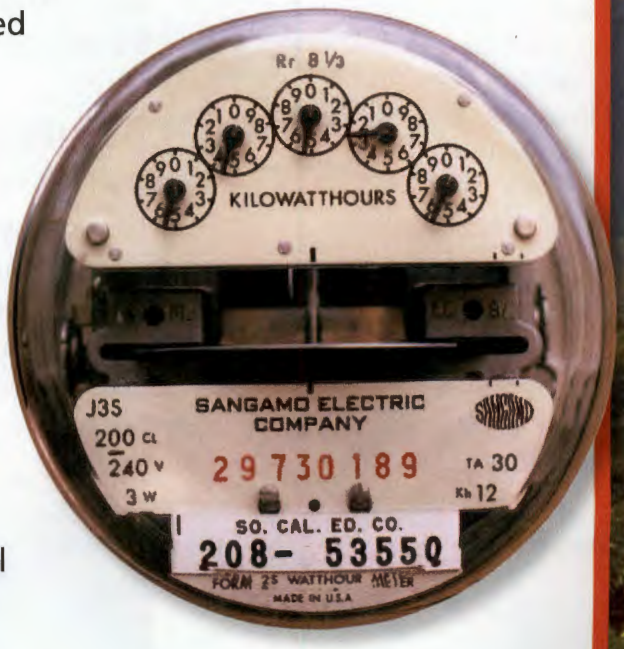
To complete this investigation, you must

- survey the types of energy used in one area of your school
- classify each type of energy used as renewable or nonrenewable
- identify ways to conserve energy in that area
- prepare a written report summarizing your observations and proposing your suggestions
- follow the safety guidelines in Appendix A

Plan It!

With your group, brainstorm a list of the ways in which you think energy is used in and around your school. Select an area of the school to study, such as a classroom, the cafeteria, or the school grounds. You could also consider the school's heating or cooling system or transportation to and from school.

Then decide what type of data you will collect. When you begin your study, look for ways to reduce energy use. At the end of the chapter, you will present your group's proposal to make your school more energy-efficient.



Section 1

Fossil Fuels

CALIFORNIA Standards Focus

S 6.3.b Students know that when fuel is consumed, most of the energy released becomes heat energy.

S 6.6.a Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

- How do fuels provide energy?
- What are the three major fossil fuels?
- Why are fossil fuels considered nonrenewable resources?

Key Terms

- fuel
- energy transformation
- combustion
- fossil fuel
- hydrocarbon
- petroleum
- refinery
- petrochemical

Lab zone Standards Warm-Up

What's in a Piece of Coal?

1. Observe a chunk of coal. Record your observations in as much detail as possible, including its color, texture, and shape.
2. Now use a hand lens to observe the coal more closely.
3. Examine your coal for fossils—imprints of plant or animal remains.

Think It Over

Observing What did you notice when you used the hand lens compared to your first observations? What do you think coal is made of?

How did you travel to school today? Whether you traveled in a car or a bus, walked, or rode your bike, you used some form of energy. The source of that energy was a fuel. A **fuel** is a substance that provides energy—such as heat, light, motion, or electricity—as the result of a chemical change.

Energy Transformation and Fuels

Rub your hands together quickly for several seconds. Did they become warmer? When you moved your hands, they had kinetic energy, the energy of motion. The friction of your hands rubbing together converted the kinetic energy to thermal energy, which you felt as heat. A change from one form of energy to another is called an **energy transformation**, or an energy conversion.

Gasoline is a fossil fuel. ▶

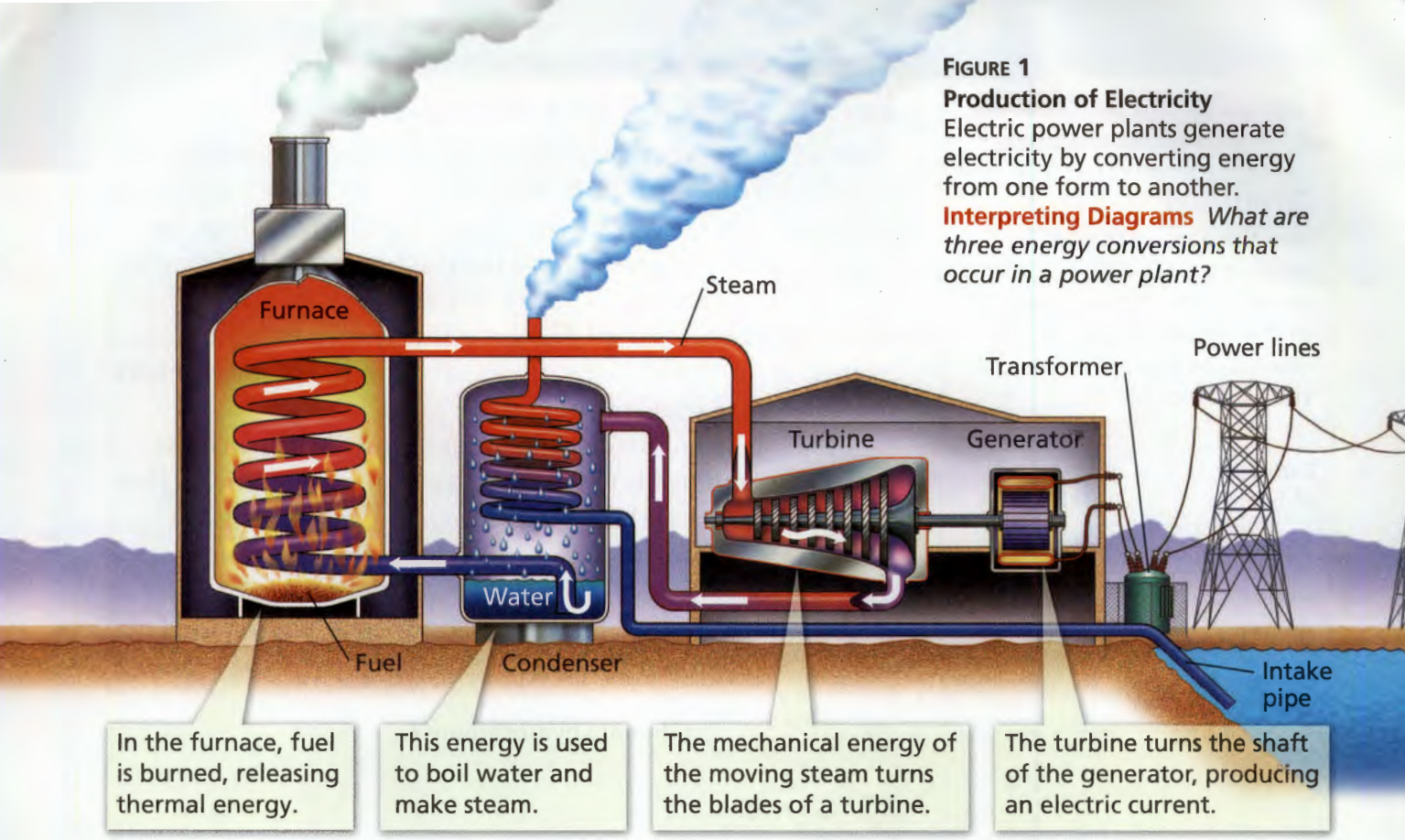


FIGURE 1
Production of Electricity
Electric power plants generate electricity by converting energy from one form to another.
Interpreting Diagrams *What are three energy conversions that occur in a power plant?*

Combustion Fuels contain stored chemical energy, which can be released by **combustion,** or burning. **When fuels are burned, chemical energy is released as heat and light. These forms of energy can be used to generate other forms of energy, such as motion or electricity.** Ultimately, however, most of the released energy is converted into heat.

For example, when the gasoline in a car's engine is burned, some of the chemical energy stored in the gasoline is converted into thermal energy. This thermal energy is then converted to kinetic energy that moves the car. Then when the brakes are applied, the car's kinetic energy is converted into heat as the brake pads rub against part of the wheels.

Production of Electricity The chemical energy stored in fuels can be used to generate electricity. In a typical electric power plant, the thermal energy produced by burning fuel is used to boil water, making steam, as shown in Figure 1. The mechanical energy of the steam then turns a turbine. The turbine is connected to a generator, which consists of powerful magnets surrounded by coils of copper wire. As the magnets turn inside the wire coil, an electric current is produced. This current flows through power lines to homes and industries.

Reading Checkpoint **What energy transformations occur in a car's engine?**

Go Online SCI LINKS NSTA
For: Links on fossil fuels
Visit: www.SciLinks.org
Web Code: scn-0551

Lab zone Skills Activity

Graphing

Use the data in the table below to make a circle graph showing the uses of energy in the United States. (To review circle graphs, see the Skills Handbook.)

End Use of Energy	Percent of Total Energy
Transportation	26.5
Industry	38.1
Homes and businesses	35.4

What Are Fossil Fuels?

Most of the energy used today comes from organisms that lived hundreds of millions of years ago. As these plants, animals, and other organisms died, their remains piled up. Layers of sand, rock, and mud buried the dead organisms. Over time, heat and the pressure of sediments changed the material into other substances. **Fossil fuels** are the energy-rich substances formed from the remains of organisms. **The three major fossil fuels are coal, oil, and natural gas.**

Fossil fuels are made of hydrocarbons. **Hydrocarbons** are chemical compounds that contain carbon and hydrogen. During combustion, carbon and hydrogen combine with oxygen from the air to form carbon dioxide and water. Combustion releases energy in the forms of heat and light. The combustion of fossil fuels provides more energy per kilogram than the combustion of other fuels such as wood.

Reading Checkpoint What are hydrocarbons?

Coal

Coal is a solid fossil fuel formed from plant remains. Figure 2 shows the process by which coal forms. People have burned coal to produce heat for thousands of years. Today, coal makes up about 23 percent of the fuel used in the United States. Most of that coal fuels electrical power plants.

Before coal can be used to produce energy, it has to be mined, or removed from the ground. Miners use machines to chop the coal into chunks and lift it to the surface. Coal mining can be a dangerous job. Thousands of miners have been killed or injured in accidents in the mines. Many more suffer from lung diseases. Fortunately, modern safety procedures and better equipment have made coal mining safer.

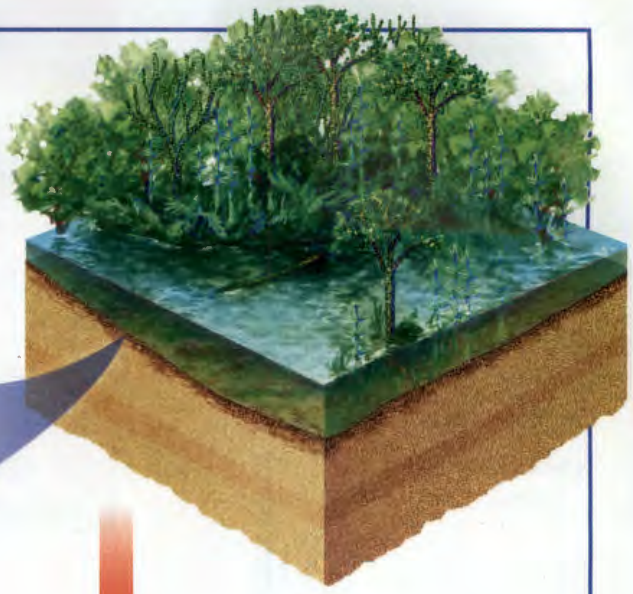
Coal is the most plentiful and inexpensive fossil fuel in the United States. It is fairly easy to transport and provides a lot of energy when burned. But coal also has some disadvantages. Coal mining can increase erosion. One type of coal mining leaves large open pits in the ground, and runoff from these coal mines can cause water pollution.

Burning most types of coal results in more air pollution than other fossil fuels. This pollution can be reduced to some extent by treating the coal before burning. Many pollutants can also be filtered out after combustion before they can reach the atmosphere. Nevertheless, concerns about pollution continue to limit the widespread use of coal.

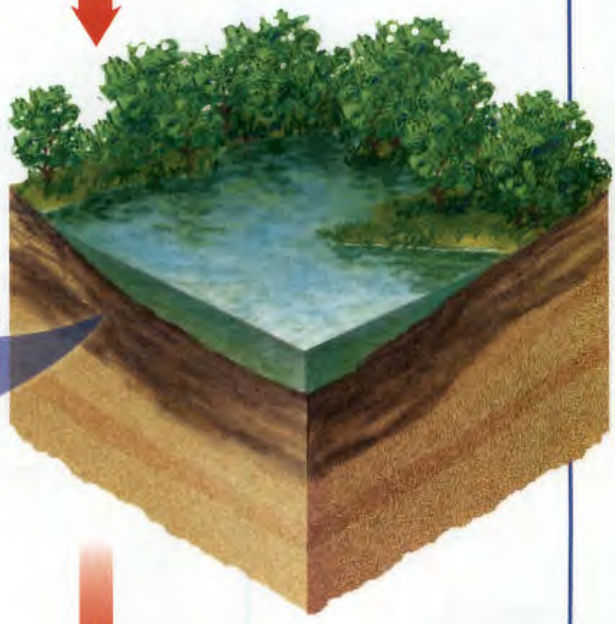
FIGURE 2

Coal Formation

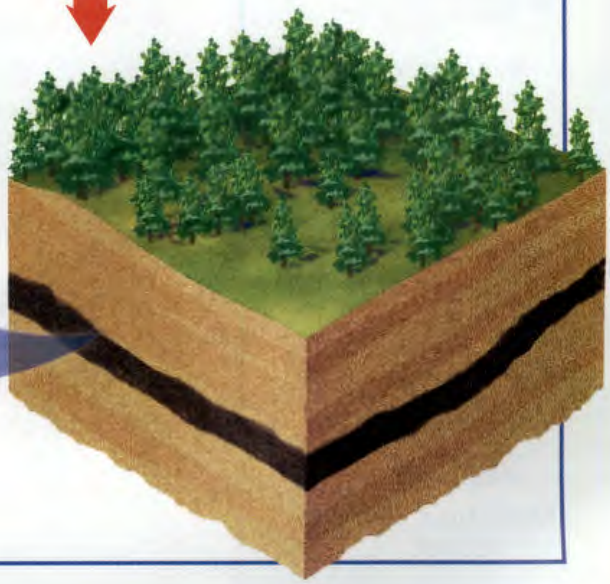
Coal is formed from the remains of trees and other plants that grew in swamps hundreds of millions of years ago. **Relating Diagrams and Photos** *What are two ways that peat and coal differ?*



Decomposing Plant Matter
When swamp plants die, their decomposing remains build up.

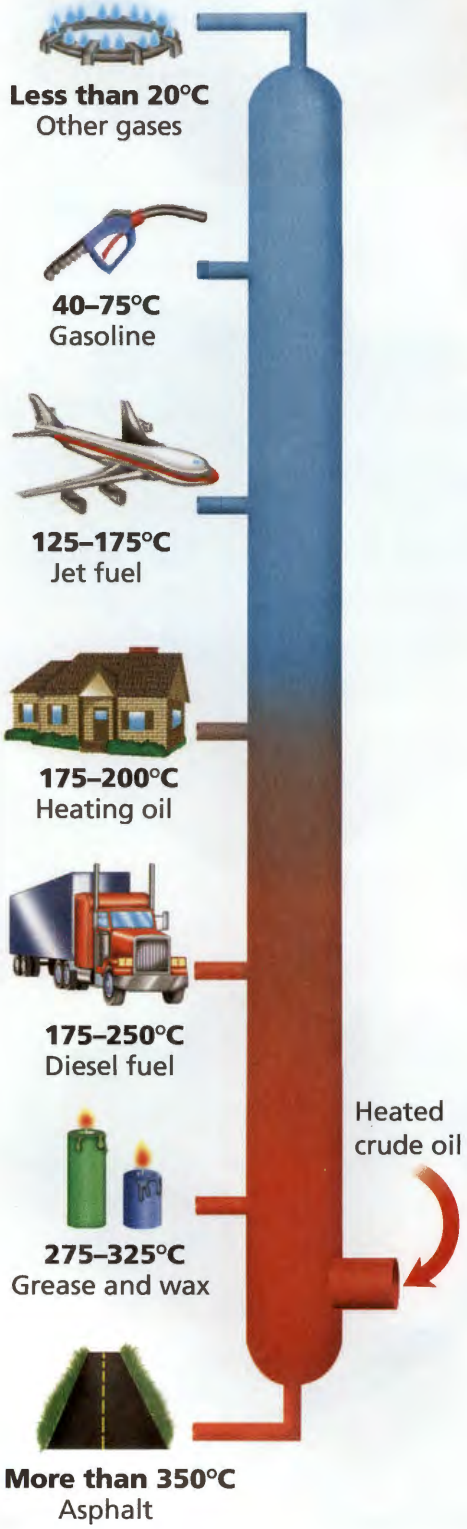


Peat
Over time, plant remains pile up and form peat. Peat can be burned as fuel.



Coal
Under increasing pressure from sediments, peat is compacted. Eventually, peat becomes coal. Coal is a more efficient fuel than peat.

FIGURE 3
Oil Production
Crude oil is first pumped out of the ground and then refined. In the refining process, crude oil is heated and separated to make different products.



Oil

Oil is a thick, black, liquid fossil fuel. It formed from the remains of small organisms that lived in oceans and shallow inland seas hundreds of millions of years ago. **Petroleum** is another name for oil, from the Latin words *petra* (rock) and *oleum* (oil). Petroleum accounts for more than one third of the world's energy production. Fuel for most cars, airplanes, trains, and ships comes from petroleum. In addition, many homes are heated by oil.

Most oil deposits are located underground in tiny holes in sandstone or limestone. Because oil deposits are usually located deep below the surface, finding oil is difficult.

Oil Products When oil is first pumped out of the ground, it is called crude oil. To be made into useful products, such as gasoline, crude oil must undergo a process called refining. A factory in which crude oil is heated and separated into fuels and other products is called a **refinery**.

In Figure 3, you can see some of the products made by refining crude oil. Many other products you use every day are also made from crude oil. **Petrochemicals** are compounds that are made from oil. Petrochemicals are used to make plastics and the synthetic materials used in many common objects. Petrochemicals are also used in paints, medicines, and cosmetics.

Oil Resources Oil's low cost in the past and its ease-of-use have made it an important resource in our modern economy. However, as with the combustion of all fossil fuels, the combustion of oil in cars and power plants produces air pollution. Accidental oil spills sometimes pollute the oceans and harm sea life. Also, existing oil supplies are being used up faster than new supplies are being discovered.

Natural Gas

Natural gas is a mixture of methane and other gases. Natural gas forms from some of the same organisms as oil. Because it is less dense than oil, natural gas often rises above an oil deposit, forming a pocket of gas.

Pipelines are often used to transport natural gas from its source to the places where it is used. If all the gas pipelines in the United States were connected, they would reach to the moon and back—twice! Natural gas can also be compressed into a liquid and transported in huge ships. Compressed natural gas is also used in trucks and buses.

Natural gas has several advantages. It produces large amounts of energy but lower levels of many air pollutants than coal or oil. It is also easy to transport once a network of pipelines is built. One disadvantage of natural gas is that it is highly flammable. A gas leak can cause a violent explosion and fire.

Gas companies help to prevent dangerous explosions from leaks. If you use natural gas in your home, you probably are familiar with the "gas" smell that alerts you whenever there is unburned gas in the air. Natural gas actually has no odor at all. Gas companies add a chemical with a distinct smell to the gas so that people can detect a gas leak.

Reading Checkpoint What is one advantage of using natural gas?

FIGURE 4
Natural Gas Pipelines
More than 2,500,000 kilometers of natural gas pipelines run underground in the United States. Here, a technician prepares a new section of pipe.

Math: Statistics, Data Analysis, and Probability 6.3.2

Math Analyzing Data

Fuels and Electricity

The circle graph shows which energy sources are used to produce electricity in the United States.

1. **Reading Graphs** What does each wedge of the circle represent?
2. **Interpreting Data** Which energy source is used to generate most of the electricity in the United States?
3. **Drawing Conclusions** What percentage of the electricity production in the United States relies on fossil fuels?
4. **Predicting** How might the circle graph differ 50 years from now? Give reasons to support your prediction.

United States Electricity Production by Energy Source

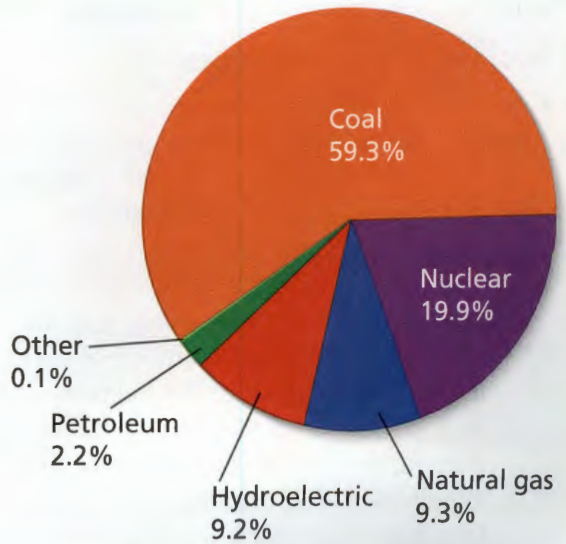


FIGURE 5
Supply and Demand
In the 1970s, a group of oil-exporting nations reduced their oil exports to the United States. Gasoline shortages resulted.

Fuel Supply and Demand

As natural resources, fuels can be classified as either renewable or nonrenewable. Renewable resources are either always available or are naturally replaced in a short time. Nonrenewable resources cannot be replaced in a useful time frame.

The many advantages of using fossil fuels as an energy source have made them essential to modern life. **But since fossil fuels take hundreds of millions of years to form, they are considered nonrenewable resources.** For example, Earth's known oil supplies took some 500 million years to form.

Many nations that consume large amounts of fossil fuels have relatively small supplies. They have to buy oil, natural gas, or coal from other nations. The United States, for example, uses about one third of all the oil produced in the world. But only 3 percent of the world's oil supply is located in this country. The difference must be purchased from other countries. The uneven distribution of oil supplies has often been a cause of political problems in the world.

Known coal supplies are high compared to current demand. However, the world's demand for oil and natural gas has been growing faster than new supplies are being found. This could lead to higher prices in the future as these resources become scarcer. Eventually, other types of energy resources will be needed to help meet the world's energy needs.

Section 1 Assessment

S 6.3.b, 6.6.a
E-LA: Reading 6.1.0

Vocabulary Skill **Prefixes** How does knowing the meaning of the prefix *hydro-* help you remember what happens to hydrocarbons during combustion?

Reviewing Key Concepts

1. a. **Defining** What is a fuel?
   b. **Explaining** How do fuels provide energy?
   c. **Sequencing** Describe in order the energy transformations that occur in the production of electricity at a power plant.
2. a. **Listing** What are the three main fossil fuels?
   b. **Comparing and Contrasting** List an advantage and a disadvantage of each fossil fuel discussed in this section.
   c. **Making Judgments** Suppose you were designing a new fossil fuel power plant. Which fossil fuel would you recommend? Give two reasons for your answer.
3. a. **Reviewing** Why are fossil fuels considered nonrenewable resources?
   b. **Problem Solving** List three things you can do to reduce your dependence on fossil fuels.

Lab zone At-Home Activity

Heating Fuel Pros and Cons Talk to an adult family member to find out what type of energy source is used to heat or cool your home. Then, with the family member, list some advantages and disadvantages of that type of fuel. Share what you learned with your classmates. What fuel source is used by the majority of students in your class?

Section 2

Renewable Sources of Energy

CALIFORNIA Standards Focus

S 6.6.a Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

S 6.6.b Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.

- What forms of energy does the sun provide?
- What are some renewable sources of energy?

Key Terms

- solar energy
- hydroelectric power
- biomass fuel
- gasohol
- geothermal energy
- tide

Lab zone Standards Warm-Up

Can You Capture Solar Energy?

1. Pour 250 milliliters of water into each of two resealable, clear plastic bags.
2. Record the water temperature in each bag. Seal the bags.
3. Put one bag in a dark or shady place. Put the other bag in a place where it will receive direct sunlight.
4. Predict what the temperature of the water in each bag will be after 30 minutes.
5. Record the temperatures after 30 minutes.

Think It Over

Developing Hypotheses How did the water temperature in each bag change? What could account for these results?

You've just arrived at the campsite for your family vacation. The sun streaming through the trees warms your face. A breeze stirs, carrying with it the smell of a campfire. Maybe you'll start your day with a dip in the warm water of a nearby hot spring.

You might be surprised to learn that even in these woods, you are surrounded by energy resources. The sun warms the air, the wind blows, and heat from inside Earth warms the waters of the spring. These sources of energy are all renewable—they are constantly being supplied. Scientists are trying to find ways to put these renewable energy resources to work to meet people's energy needs.

Campers surrounded by renewable resources ▶

FIGURE 6
Solar Collector
This mirror collects energy from the sun and powers an electric plant in New South Wales, Australia. **Inferring** *Why is the Australian desert a practical location for a solar power plant?*

Harnessing the Sun's Energy

The warmth you feel on a sunny day is **solar energy**, or energy from the sun. **The sun constantly gives off energy in the forms of light and heat.** Solar energy is the source, directly or indirectly, of most other renewable energy resources. In one day, Earth receives enough solar energy to meet the energy needs of the entire world for 40 years. Solar energy does not cause pollution, and it will not run out for billions of years.

One problem with solar energy is that it is only available when the sun is shining. Efficient, low-cost solar energy storage systems are not readily available. Another problem is that sunlight is very spread out. To obtain a large amount of power, it is necessary to collect solar energy from a large area. For this reason, it remains expensive to produce electricity using solar energy.

Solar Power Plants One way to capture the sun's energy involves using giant mirrors. In a solar power plant, rows of mirrors focus the sun's rays to heat a tank of water. The water boils, creating steam, which can then be used to generate electricity.

Solar Cells Solar energy can be converted directly into electricity in a solar cell. A solar cell has a negative and a positive terminal, like a battery. When light hits the cell, an electric current is produced. Solar cells power some calculators, lights, and other small devices. However, it would take more than 5,000 solar cells the size of your palm to produce enough electricity for a typical American home.

Passive Solar Heating Solar energy can be used to heat buildings with passive solar systems. A passive solar system converts sunlight into thermal energy, which is then distributed without using pumps or fans. Passive solar heating is what occurs in a parked car on a sunny day. Solar energy passes through the car's windows and heats the seats and other car parts. These parts transfer heat to the air, and the inside of the car warms. The same principle can be used to heat a home.

Active Solar Heating An active solar system captures the sun's energy, and then uses pumps and fans to distribute the heat. First, light strikes the dark metal surface of a solar collector. There, it is converted to thermal energy. Water is pumped through pipes in the solar collector to absorb the thermal energy. The heated water then flows to a storage tank. Finally, pumps and fans distribute the heat throughout the building.

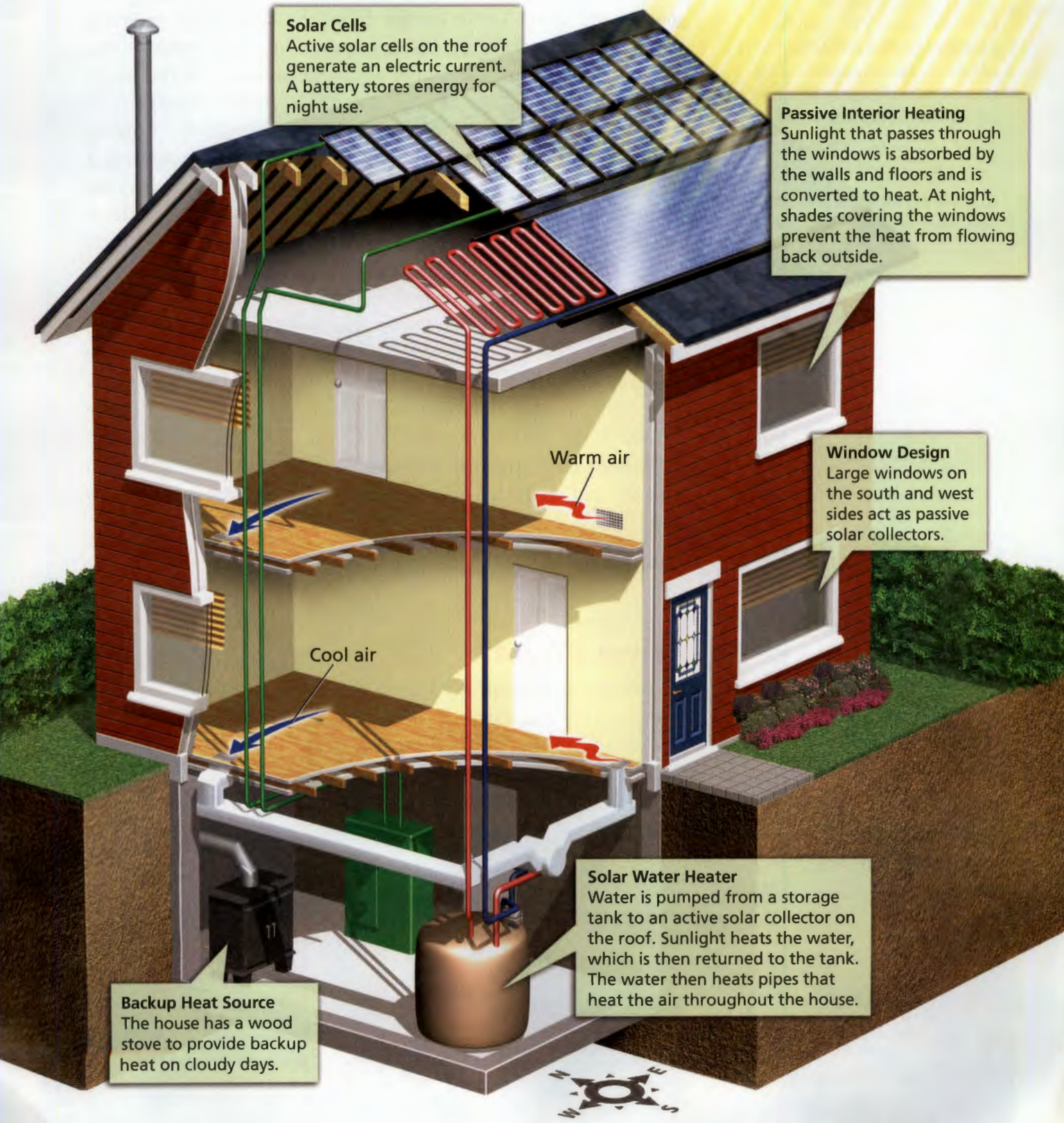
Reading Checkpoint How do solar cells work?

Video Field Trip
Discovery Channel School
Energy Resources

FIGURE 7

Solar House

A solar house uses passive and active heating systems to convert solar energy into heat and electricity.



Lab zone Try This **Activity**

Blowing in the Wind

You can make a model that shows how wind can do the work necessary to produce energy. Using a pinwheel and other materials, construct a device that lifts a small object when the wind blows. Then use a fan to test your device.

Making Models What parts of a wind power plant do the fan and pinwheel represent?

Hydroelectric Power

The sun is one source of renewable energy. **Other renewable sources of energy include water, the wind, biomass fuels, geothermal energy, and the tides.**

Solar energy is the indirect source of water power. Recall that in the water cycle, energy from the sun heats water on Earth's surface, forming water vapor. The water vapor condenses and falls back to Earth as rain and snow. As the water flows over the land, it provides another source of energy.

Hydroelectric power is electricity produced by flowing water. A dam across a river blocks the flow of water, creating a body of water called a reservoir. When a dam's control gates are opened, water flows through tunnels at the bottom of the dam. As the water moves through the tunnels, it turns turbines, which are connected to a generator.

Today, hydroelectric power is the most widely used source of renewable energy. Unlike solar energy, flowing water provides a steady supply of energy. Once a dam and power plant are built, producing electricity is inexpensive and does not create air pollution. But hydroelectric power has limitations. In the United States, most suitable rivers have already been dammed. And dams can have negative effects on the environment, such as sediment build-up and the potential for disaster caused by dam failure.

Reading Checkpoint **What is hydroelectric power?**

Wind Power

Like water power, wind power is also an indirect form of solar energy. The sun heats Earth's surface unevenly. As a result of this uneven heating, different areas of the atmosphere have different temperatures and air pressures. The differences in pressure cause winds as air moves from one area to another.

FIGURE 8
Renewable Energy Sources

This dam and wind farm use renewable sources of energy to generate power. The car runs on vegetable oil, a type of biomass fuel that is also renewable.

Comparing and Contrasting *How are biomass fuels similar to energy sources such as wind and water? How are they different?*

Wind can be used to turn a turbine and generate electricity. Large wind farms consist of many wind turbines, which are modern versions of windmills. These wind farms are located in regions such as Central California where the wind blows strongly and steadily, so the most power can be produced.

Wind is perhaps the fastest growing energy resource. Wind power is renewable and does not cause pollution. The cost of energy produced by wind turbines has been falling steadily thanks to improvements in technology. In areas with strong winds, wind turbines can produce electricity at a cost that is competitive with those of fossil-fuel plants.

But wind power does have some drawbacks. Many areas do not have sufficiently strong and steady winds to support wind farms. Wind farms require a lot of land, although the land can often be used for other purposes. Also, the wind often blows the strongest in scenic areas, such as along the shore or on mountaintops, where people may object to building wind turbines.

Biomass Fuels

Wood was probably the first fuel ever used for heat and light. Wood belongs to a group of fuels called **biomass fuels,** which are made from material that was once part of a living thing. Other biomass fuels include leaves, food wastes, and manure.

Aside from being burned as fuel, biomass materials can also be converted into other fuels. For example, some crops can be used to make alcohol. Adding the alcohol to gasoline forms a mixture called **gasohol.** Gasohol can be used as fuel for cars. Bacteria can produce methane gas when they decompose biomass materials in landfills. That methane can be used to heat buildings.

Biomass fuels are renewable resources. But it takes time for new trees to replace those that have been cut down. And producing alcohol and methane in large quantities is expensive. As a result, biomass fuels are not widely used today in the United States. But as fossil fuels become scarcer, biomass fuels may play a larger role in meeting energy needs.

Go Online
SCI LINKS NSTA

For: Links on renewable energy
Visit: www.SciLinks.org
Web Code: scn-0552

Tapping Earth's Energy

Below Earth's surface are pockets of very hot liquid rock called magma. In some places, magma is very close to the surface. The intense heat from Earth's interior that warms the magma is called **geothermal energy**.

In certain regions, such as Iceland and New Zealand, magma heats underground water to the boiling point. In these places, the hot water and steam can be valuable sources of energy. For example, in Reykjavík, Iceland, 90 percent of homes are heated by water warmed underground in this way. Geothermal energy can also be used to generate electricity, as shown in Figure 9.

Geothermal energy is an unlimited source of cheap energy. But it does have disadvantages. There are only a few places where magma comes close to Earth's surface. Elsewhere, very deep wells would be needed to tap this energy. Drilling deep wells is very expensive. Even so, geothermal energy is likely to play a growing part in meeting energy needs in some regions.

Reading Checkpoint **How can geothermal energy be used to generate electricity?**

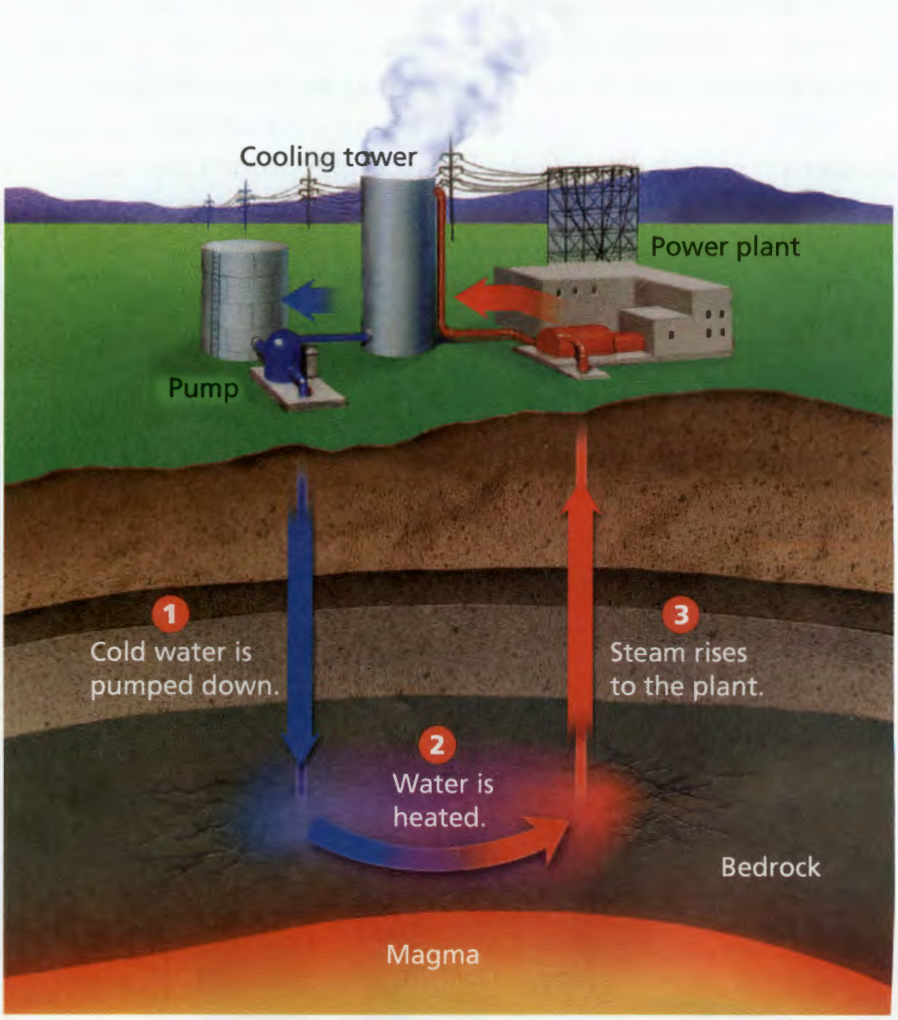


FIGURE 9
Geothermal Energy
A geothermal power plant uses heat from Earth's interior as an energy source. Cold water is piped deep into the ground, where it is heated by magma. The resulting steam and hot water can be used for heat or to generate electricity.
Making Generalizations *What are one advantage and one disadvantage of geothermal energy?*

Tidal Energy

You have already learned that flowing water in a river can be used to produce electricity. Another source of moving water is the tides. The **tides** are the regular rise and fall of Earth's waters along its shores. The tides are caused by the gravitational pull of the moon and sun. Along some coastlines, enormous amounts of water move into bays and river mouths at high tide. This water flows back out to sea when the tide falls.

A few tidal power plants have been built to take advantage of this regular motion. Such power plants typically consist of a low, gated dam across the entrance to a shallow bay or river. As the tide rises, the dam's gates open so that water flows in. As the tide retreats, the gates shut to trap the water behind. Gravity pulls the trapped water back to the sea through tunnels. The energy of the water flowing through these tunnels generates electricity, as in a hydroelectric power plant.

Although tidal power is a clean, renewable source of energy, it has several limitations. Harnessing tidal power is practical only where there is a large difference between high and low tides—at least 4 or 5 meters. There are only a few places in the world where such a large difference occurs. Also, a dam across a bay would block boats and fish from passing through. Therefore, tidal power is likely to remain a limited source of energy.

FIGURE 10
Tidal Power Plant
This large tidal power plant in France is used to generate electricity.

Section 2 Assessment

S 6.6.a, 6.6.b, E-LA: Reading 6.2.2, Writing 6.2.3

Target Reading Skill **Comparing and Contrasting** Complete a table comparing the pros and cons of solar, water, wind, and geothermal energy resources.

Reviewing Key Concepts

1. a. **Identifying** What two forms of energy does the sun supply?
   b. **Explaining** What are two reasons that solar energy has not replaced energy from fossil fuels?
   c. **Applying Concepts** A friend of yours argues that shopping malls should use solar energy to conserve fossil fuels. How would you respond?
2. a. **Listing** List five renewable energy sources other than solar energy.
   b. **Classifying** Which of the renewable energy sources that you listed are actually indirect forms of solar energy? Explain.
   c. **Predicting** Which source of renewable energy do you think is most likely to be used in your community within the next 20 years? Explain your answer.

Writing in Science

Research Report Use published materials and Internet resources to write a one-page research report about one of the energy resources discussed in this chapter. Discuss the energy resource's advantages and disadvantages. Be sure to also discuss its current status and environmental impacts. Include a brief bibliography.

Lab zone **Technology Lab**
Full Inquiry

S 6.3.a, 6.6.a

Design and Build a Solar Cooker

Materials

glue and tape

3 sheets of aluminum foil

3 sheets of oaktag paper

3 thermometers and wooden or plastic stirrers

clock or watch

scissors

frozen vegetables

Problem What is the best shape for a solar cooker?

Skills Focus designing a solution, evaluating the design

Procedure

PART 1 Research and Investigate

1. Glue a sheet of aluminum foil, shiny side up, to each sheet of oaktag paper. Before the glue dries, gently smooth out any wrinkles in the foil.
2. Bend one sheet into a U shape. Leave another sheet flat. Bend another sheet into a shape of your own choosing.
3. Predict which shape will produce the largest temperature increase when placed in the sun. Write down your prediction and explain your reasons.
4. Place the aluminum sheets in direct sunlight. Use wood blocks or books to hold the sheets in position, if necessary.
5. Record the starting temperature on each thermometer.
6. Place the thermometer bulbs in the center of the aluminum shapes. After 15 minutes, record the final temperature on each thermometer.

PART 2 Design and Build

7. Using what you learned in Part 1, design a solar cooker that can cook frozen vegetables. Your solar cooker should
   - be no larger than 50 cm on any side
   - cook the vegetables in less than 10 minutes
   - be made of materials approved by your teacher
8. Prepare a written description of your plan that includes a sketch of your cooker. Include a list of materials and an operational definition of a "well-cooked" vegetable. Obtain your teacher's approval for your design. Then build your solar cooker.

PART 3 Evaluate and Redesign

9. Test your solar cooker by spearing some frozen vegetables on the stirrers. Time how long it takes to cook the vegetables. Make note of any problems with your solar cooker design.

10. Based on your test, decide how you could improve the design of your cooker. Then make any desired changes to your cooker and test how the improved cooker functions.

Analyze and Conclude

1. **Identifying a Need** In what situations might it be important to have an efficient cooker that does not use fuel?

2. **Designing a Solution** How did you incorporate what you learned in Part 1 into your design in Part 2? For example, which shape did you use in your cooker design?

3. **Evaluating the Design** When you tested your solar cooker, what problems did you encounter?

4. **Redesigning** In what ways did you change your design for your second test? How did the redesign improve the performance of your cooker?

5. **Working With Design Constraints** Why might it be important for solar cookers to use inexpensive, readily available materials?

6. **Evaluating the Impact on Society** How can solar-powered devices help meet the world's future energy needs? What limitation do solar-powered devices have?

Communicate

Design an advertisement for your solar cooker that will appear in a camping magazine. Make sure your ad describes the benefits of solar cookers in general, and of your design in particular.

Section 3

Nuclear Energy

CALIFORNIA Standards Focus

S 6.6.a Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

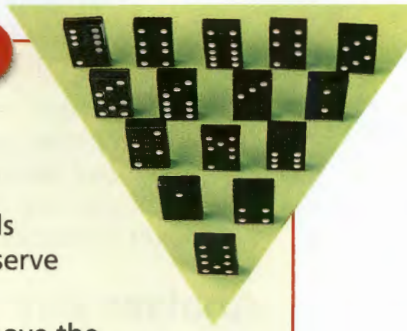
S 6.6.b Students know different natural energy and material resources, including air, soil, rocks, minerals, petroleum, fresh water, wildlife, and forests, and know how to classify them as renewable or nonrenewable.

- What happens during a nuclear fission reaction?
- How does a nuclear power plant produce electricity?
- How does a nuclear fusion reaction occur?

Key Terms

- nucleus
- nuclear fission
- reactor vessel
- fuel rod
- control rod
- meltdown
- nuclear fusion

Lab zone Standards **Warm-Up**



Why Do They Fall?

1. Line up 15 dominoes to form a triangle.
2. Knock over the first domino so that it falls against the second row of dominoes. Observe the results.
3. Set up the dominoes again, but then remove the dominoes in the third row from the lineup.
4. Knock over the first domino again. Observe what happens.

Think It Over

Inferring Suppose each domino produced a large amount of energy when it fell over. Why might it be helpful to remove the dominoes as you did in Step 3?

Wouldn't it be great if people could use the same method as the sun to produce energy? The kind of reactions that power the sun involve the central cores of atoms. The central core of an atom that contains the protons and neutrons is called the **nucleus** (plural *nuclei*). Reactions that involve nuclei, called nuclear reactions, result in tremendous amounts of energy. Two types of nuclear reactions are fission and fusion.

Nuclear Fission

Nuclear reactions convert matter into energy. As part of his theory of relativity, Albert Einstein developed a formula that described the relationship between energy and matter. You have probably seen this famous equation: $E = mc^2$. In the equation, the E represents energy and the m represents mass. The c, which represents the speed of light, is a very large number. This equation states that when matter is changed into energy, an enormous amount of energy is released.

▲ Albert Einstein 1879–1955

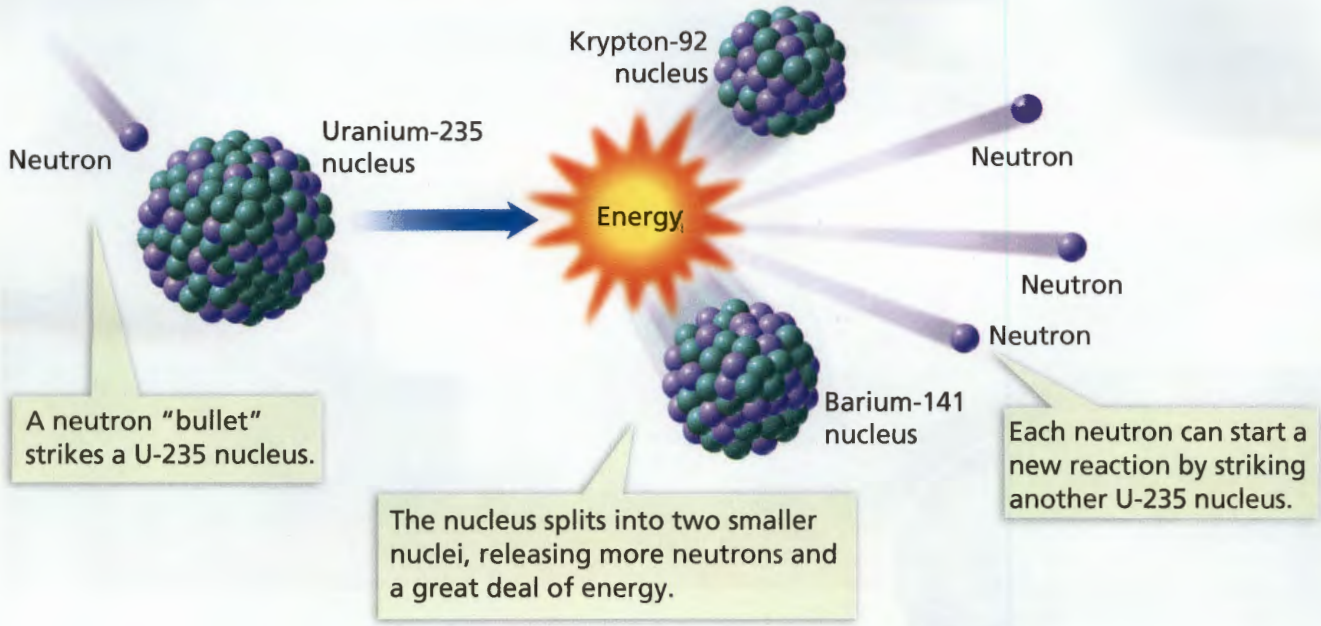


FIGURE 11
Nuclear Fission
A great deal of energy is released in a nuclear fission reaction.
Interpreting Diagrams *How does a nuclear fission reaction begin?*

Fission Reactions **Nuclear fission** is the splitting of an atom's nucleus into two smaller nuclei. The fuel for the reaction is a large atom that has an unstable nucleus, such as uranium-235 (U-235). A neutron is shot at the U-235 atom at high speed. **When the neutron hits the U-235 nucleus, the nucleus splits apart into two smaller nuclei and two or more neutrons.** The total mass of all these particles is a bit less than the mass of the original nucleus. The small amount of mass that makes up the difference has been converted into energy—a lot of energy, as described by Einstein's equation.

Meanwhile, the fission reaction has produced more neutrons. If any of these neutrons strikes another nucleus, the fission reaction is repeated. More neutrons and more energy are released. If there are enough nuclei nearby, the process repeats in a chain reaction, just like a row of dominoes falling. In a nuclear chain reaction, the amount of energy released increases rapidly with each step in the chain.

Energy From Fission What happens to all the energy released by these fission reactions? If a nuclear chain reaction is not controlled, the released energy causes a huge explosion. The explosion of an atomic bomb is an uncontrolled nuclear fission reaction. A few kilograms of matter explode with more force than several thousand tons of dynamite. However, if the chain reaction is controlled in a power plant, the energy is released as heat, which can then be used to generate electricity.

Reading Checkpoint **What happens in a nuclear chain reaction?**

Lab zone Skills Activity

Calculating

A pellet of U-235 produces as much energy as 615 liters of fuel oil. An average home uses 5,000 liters of oil a year. How many U-235 pellets would be needed to supply the same amount of energy?

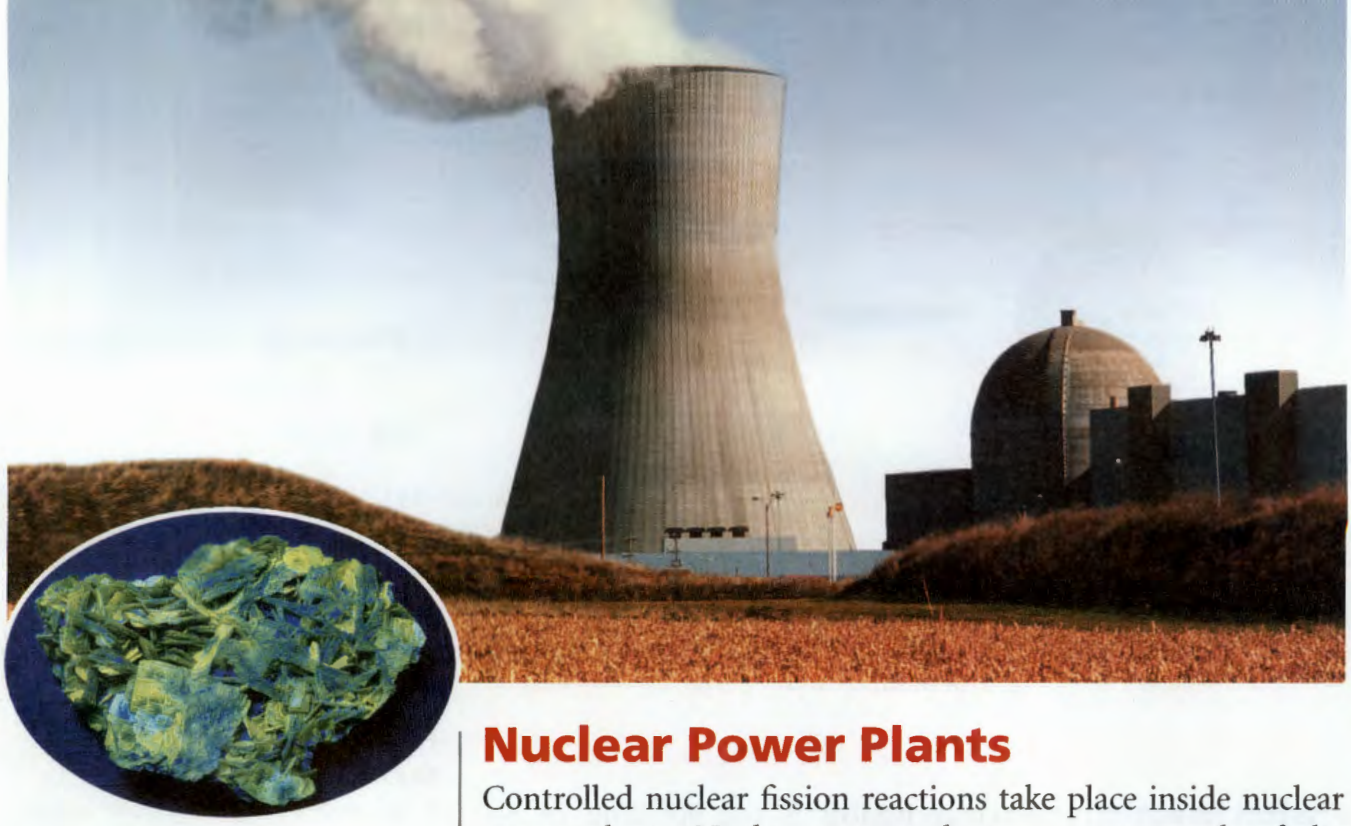


FIGURE 12
Nuclear Power
Nuclear power plants generate much of the world's electricity. The inset photo shows autunite, a uranium ore.

Nuclear Power Plants

Controlled nuclear fission reactions take place inside nuclear power plants. Nuclear power plants generate much of the world's electricity—about 20 percent in the United States and more than 70 percent in France.

Nuclear Fuel The uranium fuel for nuclear power plants is refined from uranium ores. Uranium ore is fairly abundant. However, since new uranium ore is not being created, uranium is considered a nonrenewable resource.

Energy Production Look at the nuclear power plant diagram in Figure 13. **In a nuclear power plant, the heat released from fission is used to change water into steam. The steam then turns the blades of a turbine to generate electricity.**

The **reactor vessel** is the part of the nuclear reactor where nuclear fission occurs. The reactor contains **fuel rods** that hold pellets of uranium. When several fuel rods are placed close together, a series of fission reactions occurs.

If the reactor vessel gets too hot, control rods are used to slow down the chain reactions. **Control rods,** made of the metal cadmium, are inserted between the fuel rods to slow the speed of the chain reactions.

Heat is removed from the reactor vessel by water or another fluid that is pumped through the reactor. This fluid passes through a heat exchanger. There, the fluid boils water to produce steam, which runs the electrical generator. The steam is condensed again and pumped back to the heat exchanger.

Reading Checkpoint **What is the purpose of a control rod?**

Pros and Cons Accidents at nuclear power plants have led to safety concerns. In 1986, the reactor vessel in a nuclear power plant in Chernobyl, Ukraine, overheated. The fuel rods generated so much heat that they started to melt, a condition called a **meltdown**. The excess heat caused a series of explosions, which injured or killed dozens of people. In addition, radioactive materials escaped into the environment.

Another problem is the disposal of highly radioactive wastes. Some radioactive wastes remain dangerous for many thousands of years. Scientists must find a way to store these wastes safely for a long period of time.

Nuclear plants also emit large amounts of heat to the air and nearby bodies of water. However, because nuclear plants don't burn fossil fuels, they don't produce air pollution. Since these plants don't emit carbon dioxide, some suggest that they could help to solve the problem of global warming.

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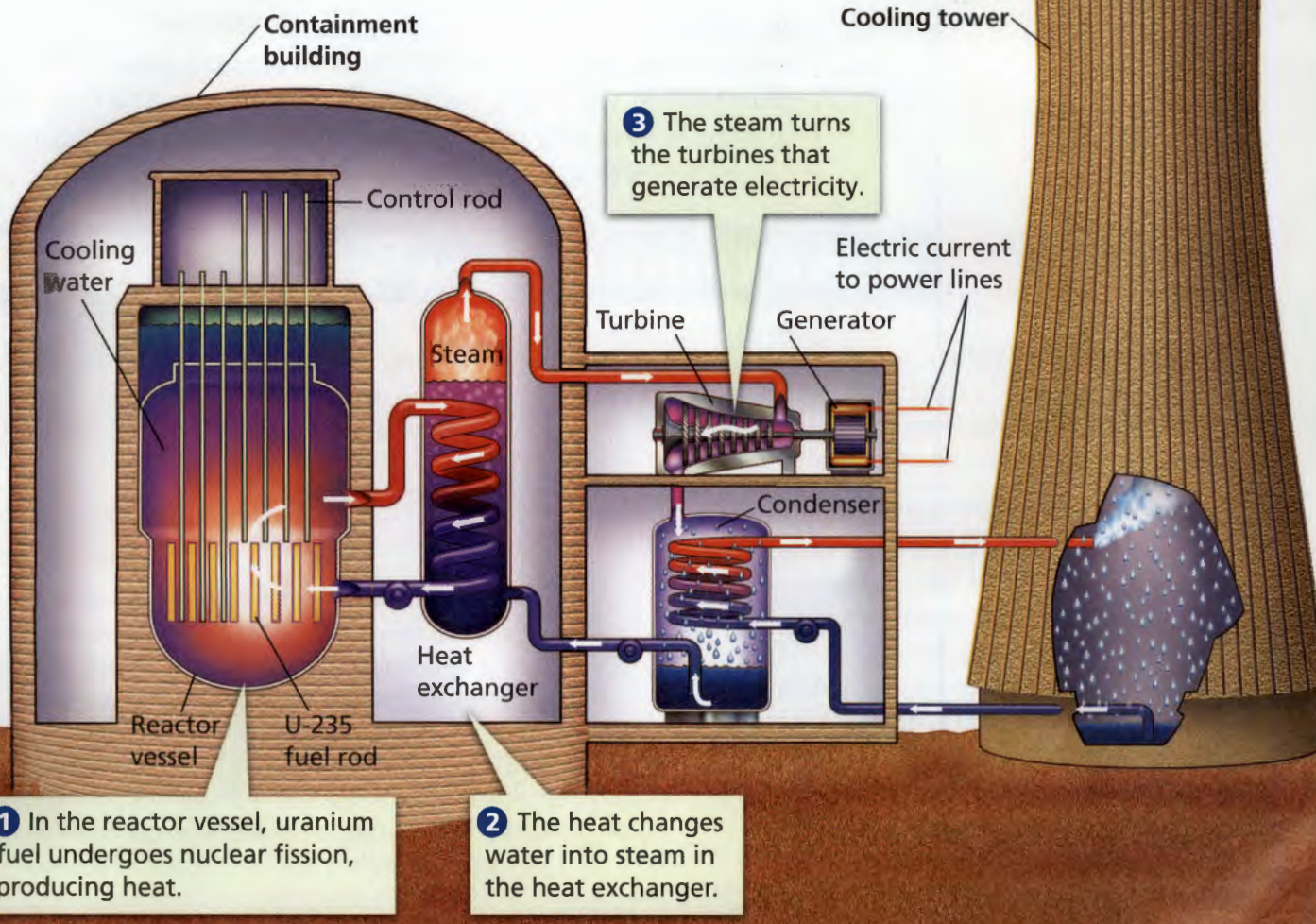
FIGURE 13
Nuclear Power Plant
Nuclear fission provides the energy to generate electricity in a nuclear power plant. **Interpreting Diagrams** *In what part of the power plant does nuclear fission occur?*



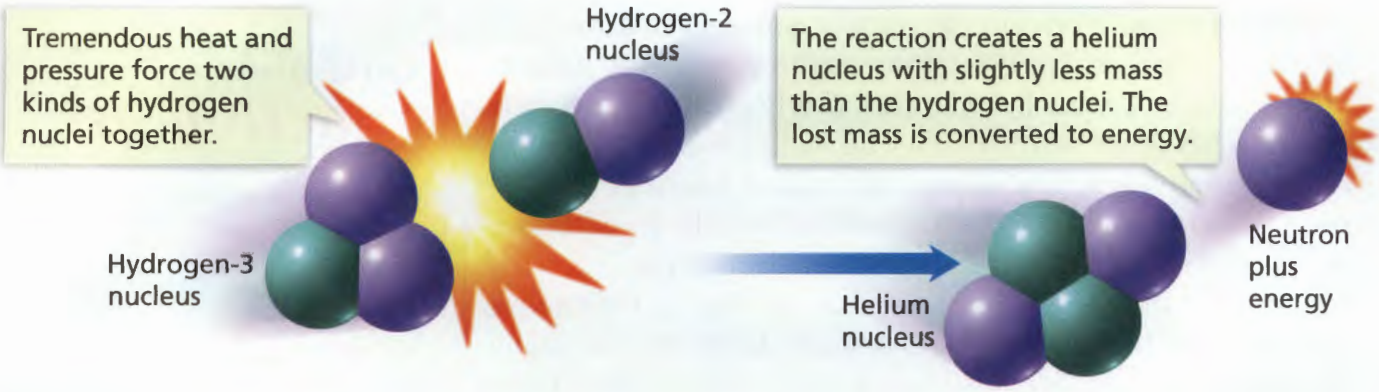


FIGURE 14
Nuclear Fusion
In nuclear fusion, two hydrogen nuclei are forced together, forming a helium nucleus, a neutron, and energy.
Interpreting Diagrams *What is released during a fusion reaction?*

The Quest to Control Fusion

Nuclear fusion is the combining of two atomic nuclei to produce a single larger nucleus. **In nuclear fusion, two hydrogen nuclei combine to create a helium nucleus, which has slightly less mass than the two hydrogen nuclei. The lost mass is converted to large amounts of energy.**

Nuclear fusion is the process by which the sun produces energy. On Earth, fusion is a promising future energy source. Fusion fuels are readily available—water contains a form of hydrogen that could be used. Since its fuel can be found in water, fusion is considered a renewable energy source. Fusion would not produce air pollution. And unlike fission, fusion would not produce long-lived radioactive wastes. However, fusion can take place only at extremely high pressures and temperatures. The construction of a practical fusion reactor is a major engineering challenge that may take many years to complete.

Section 3 Assessment

S 6.6.a, 6.6.b, E-LA: Reading 6.2.2

Target Reading Skill **Comparing and Contrasting** Create a compare/contrast table showing the similarities and differences in nuclear fission and nuclear fusion.

Reviewing Key Concepts

1. a. **Defining** What is nuclear fission?
   b. **Sequencing** Describe the steps that occur in a nuclear fission reaction.
   c. **Classifying** Is uranium a renewable or nonrenewable resource? Explain.
2. a. **Identifying** What type of nuclear reaction produces electricity in a nuclear power plant?
   b. **Explaining** Explain how electricity is produced in a nuclear power plant.
   c. **Predicting** What might happen in a nuclear plant if too many control rods were removed?
3. a. **Reviewing** Define nuclear fusion.
   b. **Relating Cause and Effect** How is energy produced during a nuclear fusion reaction?

Lab zone At-Home Activity

Shoot the Nucleus With a family member, make a model of a nuclear fission reaction. Place a handful of marbles on the floor in a tight cluster, so that they touch one another. Step back about a half meter from the marbles. Shoot a marble at the cluster. Note what effect the moving marble has on the cluster. Then using a diagram, explain how this event models a nuclear fission reaction.

Section 4

Energy Conservation

CALIFORNIA Standards Focus

S 6.3.a Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.

S 6.3.b Students know that when fuel is consumed, most of the energy released becomes heat energy.

What are two ways to preserve our current energy sources?

Key Terms

- efficiency
- insulation
- energy conservation

Lab zone Standards Warm-Up

Which Bulb Is More Efficient?

1. Record the light output (listed in lumens) from the packages of a 60-watt incandescent light bulb and a 15-watt compact fluorescent bulb.
2. Place the fluorescent bulb in a lamp socket. **CAUTION:** *Make sure the lamp is unplugged.*
3. Plug in the lamp and turn it on. Hold the end of a thermometer about 8 centimeters from the bulb.
4. Record the temperature after five minutes.
5. Turn off and unplug the lamp. When the bulb is cool, remove it. Repeat Steps 2, 3, and 4 with the incandescent light bulb.

Think It Over

Inferring The 60-watt bulb uses four times as much energy as the 15-watt bulb. Does it also provide four times as much light output? If not, how can you account for the difference?

What would happen if the world ran out of fossil fuels today? The heating and cooling systems in most buildings would cease to function. Forests would disappear as people began to burn wood for heating and cooking. Cars, buses, and trains would be stranded wherever they ran out of fuel. About 70 percent of the world's electric power capacity would be idled. Since televisions, computers, and telephones depend on electricity, communication would be greatly reduced.

Although fossil fuels won't run out soon, they also won't last forever. Most people think that it makes sense to use fuels more wisely now to avoid possible fuel shortages in the future. **One way to preserve energy resources is to increase the efficiency of energy use. Another way is to conserve energy whenever possible.**

Energy Efficiency

One way to make energy resources last longer is to use fuels more efficiently. **Efficiency** is the percentage of energy that is actually used to perform work. The rest of the energy is "lost" to the surroundings, usually as heat. This heat can pollute the water and air. People have developed many ways to increase energy efficiency.

Heating and Cooling One method of increasing the efficiency of heating and cooling systems is insulation. **Insulation** is a layer of material that traps air to help block heat flow between the air inside and outside a building. You have probably seen insulation made of fiberglass, which looks like pink cotton candy.

Trapped air can act as insulation in windows, too. Many windows consist of two panes of glass with space between them. The air between the panes of glass acts as insulation.

• Tech & Design in History •

Energy-Efficient Products

Scientists and engineers have developed many technologies that improve energy efficiency and reduce energy use.

1958 Solar Cells
More than 150 years ago, scientists discovered that silicon can convert light into electricity. The first useful application of solar cells was to power the radio on a satellite. Now solar cells are even used on experimental cars like the one above.

1932 Fiberglass Insulation
Long strands of glass fibers trap air and keep buildings from losing heat. Less fuel is used for heating.

1936 Fluorescent Lighting
Fluorescent bulbs were introduced to the public at the hundredth anniversary celebration of the United States Patent Office. Because these bulbs use less energy than incandescent bulbs, most offices and schools use fluorescent lights today.

1930 1940 1950 1960

Lighting Much of the electricity used for home lighting is wasted. For example, less than 10 percent of the electricity that an incandescent light bulb uses is converted into light. The rest is given off as heat. In contrast, compact fluorescent bulbs use about one fourth as much energy to provide the same amount of light.

Transportation Engineers have improved the energy efficiency of cars by designing better engines and tires. Another way to save energy is to reduce the number of cars on the road. In many communities, public transit systems provide an alternative to driving. Other cities encourage carpooling. Many cities now set aside lanes for cars containing two or more people.

Reading Checkpoint What are two examples of insulation?

Writing in Science

Research and Write Design an advertisement for one of the energy-saving inventions described in this timeline. The advertisement may be a print, radio, or television ad. Be sure that your advertisement clearly explains the benefits of the invention.

1967 Microwave Ovens
The first countertop microwave oven for the home was introduced. Microwaves cook food by heating the water the food contains. Unlike a conventional oven, a microwave oven heats only the food. And preheating is unnecessary, saving even more energy.

1981 High-Efficiency Window Coatings
Materials that reflect sunlight were first used to coat windows in the early 1980s. This coating reduces the air conditioning needed to keep the inside of the building cool.

1997 Hydrogen-Powered Vehicles
Hydrogen fuel cells produce no polluting emissions. In 1997, two major automakers unveiled experimental hydrogen-powered cars. The first mass-produced hydrogen-powered cars are expected around 2010.

1970 1980 1990 2000

FIGURE 15
Energy Conservation
There are many ways you can conserve energy.

Ways I can conserve energy:

- ✓ Walk or ride a bike for short trips
- ✓ Recycle
- ✓ Use fans instead of air conditioners when it's hot
- ✓ Turn off the lights and television when leaving a room

Energy Conservation

Another approach to making energy resources last longer is conservation. **Energy conservation** means reducing energy use.

You can reduce your personal energy use by changing your behavior in some simple ways. For example, if you walk to the store instead of getting a ride, you are conserving the gasoline it would take to drive to the store. You can also follow some of the suggestions in Figure 15.

While these suggestions seem like small things, multiplied by millions of people they add up to a lot of energy saved for the future.

Reading Checkpoint **What are two ways you can reduce your personal energy use?**

Section 4 Assessment

S 6.3.a, 6.3.b, E-LA: Reading 6.1.0, Writing 6.2.0

Vocabulary Skill **Prefixes** The prefix *con-* and the Latin root *servare* form *conserve*, meaning "keep together" or "preserve." What is the meaning of *energy conservation*?

Reviewing Key Concepts

1. a. **Identifying** What are the two keys to preserving our current energy resources?
   b. **Applying Concepts** How does insulating buildings help to preserve energy resources? How does carpooling preserve resources?
   c. **Predicting** One office building contains only incandescent lights. The building next door contains only fluorescent lights. Predict which building has higher energy bills. Explain your answer.

Writing in Science

Energy Savings Brochure
Conduct an energy audit of your home. Look for places where energy is being lost, such as cracks around doors. Also look for ways to reduce energy use, such as running the dishwasher only when it is full. Then create a short, illustrated brochure of energy-saving suggestions. Keep the brochure where everyone can see it.

Lab zone **Consumer Lab**

Guided Inquiry

S 6.3.a, 6.7.c

Keeping Comfortable

Materials

containers and lids made of paper, glass, plastic, plastic foam, and metal

pencil

ice water

thermometers or temperature probes

beakers

hot water

clock or watch

Problem

How well do different materials prevent heat flow?

Skills Focus

measuring, controlling variables

Procedure

1. Use a pencil to poke a hole in the lid of a paper cup. Fill the cup halfway with cold water.
2. Put the lid on the cup. Insert a thermometer into the water through the hole. (If you are using a temperature probe, see your teacher for instructions.) When the temperature stops dropping, place the cup in a beaker. Add hot water to the beaker until the water level is about 1 cm below the lid.
3. Record the water temperature once every minute until it has increased by 5°C. Use the time it takes for the temperature to increase 5°C as a measure of the effectiveness of the paper cup in preventing heat transfer.
4. Choose three other containers and their matching lids to test. Design an experiment to compare how well those materials prevent heat transfer. You can use a similar procedure to the one you used in Steps 1–3.

Analyze and Conclude

1. **Measuring** In Step 2, what was the starting temperature of the cold water? How long did it take for the temperature to increase by 5°C? In which direction did the heat flow? Explain.
2. **Making Models** If the materials in Steps 1–3 represented your home in very hot weather, which material would represent the rooms in your home? The outdoor weather? The building walls?
3. **Controlling Variables** In the experiment you conducted in Step 4, what were the manipulated and responding variables? What variables were kept constant?
4. **Drawing Conclusions** Which material was most effective at preventing the transfer of heat? Which was the least effective? Explain how your data support your conclusion.
5. **Communicating** Write a paragraph explaining why the results of your experiment could be useful to people building energy-efficient structures.

Design an Experiment

Design an experiment to compare how well the materials you tested would work if the hot water were inside the cup and the cold water were outside. *Obtain your teacher's permission before carrying out your investigation.*

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Technology and Society

S 6.6.b

The Hybrid Car

How do you get from here to there? Like most people, you probably rely on cars or buses. Engines that burn fossil fuels power most of these vehicles. To conserve fossil fuels, as well as to reduce air pollution, some car companies have begun to produce hybrid vehicles.

How Are Hybrid Cars Different?

The power source for most cars is a gasoline engine that powers the transmission. Unlike conventional cars, hybrid cars use both a gasoline engine and an electric motor to turn the transmission. The generated power can be used by the transmission to turn the wheels. Or power can be converted into electricity for later use by the electric motor. Any extra electricity is stored in the car's battery. The gasoline engine in a hybrid car is smaller, more efficient, and less polluting than the engine in a conventional car.

Gasoline Engine The engine burns fuel to provide energy to the car.

Electric Motor and Generator In this model, the electric motor draws energy from the car's battery to help the car speed up. As the car slows down, the generator produces electricity to recharge the car's battery.

Transmission This device transmits power from the engine to the axle that turns the wheels.

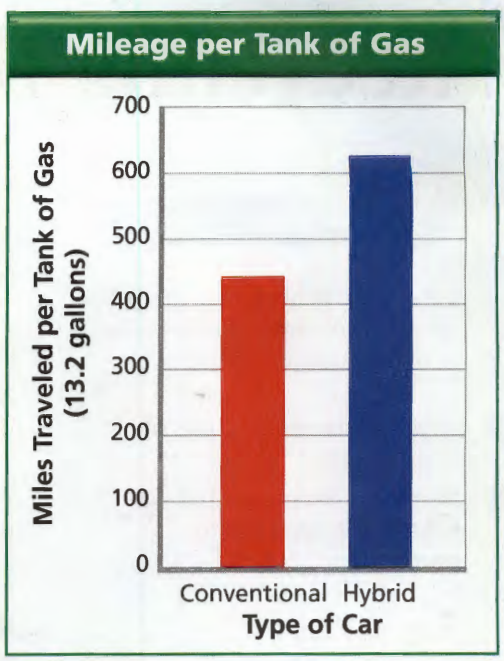
Start The car uses power from its battery to start the gasoline engine.

Accelerate When the car accelerates, the electric motor and the gasoline engine work together to power the car.

Brake When the car brakes, the motor acts like a generator and stores electrical energy in the battery.

Are Hybrid Cars the Way to Go?

Hybrid cars consume less gas per mile and emit fewer pollutants than cars that run on gasoline alone. In spite of the benefits, there are some drawbacks to hybrid cars. In general, hybrid cars have less power for climbing steep hills and less acceleration than cars with larger engines. In addition, the large batteries could be an environmental hazard if they end up in a landfill. Drivers must make trade-offs in buying any car.



Gasoline stored in the fuel tank flows to the engine, where it is burned.

Battery The car's electric motor uses energy stored in the battery.

You Decide

1. **Identify the Need** Why are some car companies developing hybrid cars?
2. **Research** Research hybrid cars currently on the market. Use your findings to list the advantages and disadvantages of hybrid-car technology.
3. **Write** Should your family's next car be a conventional or hybrid model? Use the information here and your research findings to write several paragraphs supporting your opinion.

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Stop When the car stops or idles, the gasoline engine stops. It restarts when the driver steps on the gas pedal.

Section 5

Recycling Material Resources

CALIFORNIA Standards Focus

S 6.6.c Students know the natural origin of the materials used to make common objects.

- What are three methods of handling solid waste?
- What can people do to help control the solid waste problem?

Key Terms

- municipal solid waste
- incineration
- leachate
- sanitary landfill
- recycling
- biodegradable
- composting

Lab zone Standards Warm-Up

What's in the Trash?

Your teacher will give you a trash bag. The items in the bag represent the most common categories of household waste in the United States.

1. Before you open the bag, predict what the two most common categories are.
2. Put on some plastic gloves. Open the bag and sort the trash items into categories based on what they are made of.
3. Count the number of trash items in each category. Construct a bar graph showing the number of pieces of trash in each category.

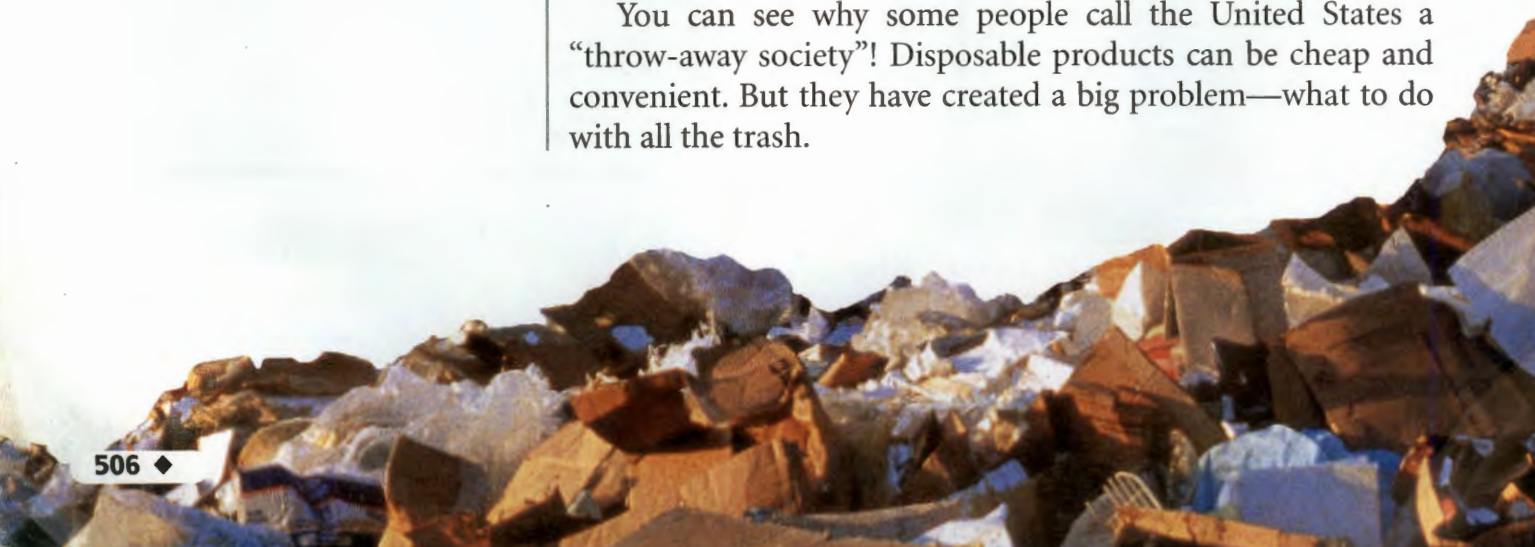
Think It Over

Interpreting Data Based on your graph, what are the two most common types of household waste? Was your prediction correct?

How much trash does your family throw away in a year? If it's your job to take the trash out, you might say that it's a large amount. Now imagine that amount multiplied by every family in the United States! Consider these facts:

- Every hour, people throw away about 2.5 million plastic bottles.
- Every day, the average person produces about 2 kilograms of trash.
- Every year, people throw away 2.8 million metric tons of plastic bags and 230 million automobile tires.

You can see why some people call the United States a "throw-away society"! Disposable products can be cheap and convenient. But they have created a big problem—what to do with all the trash.



The Problem of Waste Disposal

In their daily activities, people generate many types of waste, including used paper, empty packages, and food scraps. The waste materials produced in homes, businesses, schools, and other places in a community are called **municipal solid waste.** Other sources of solid waste include construction debris and certain agricultural and industrial wastes. **Three methods of handling solid waste are burning, burying, and recycling. Each method has advantages and disadvantages.**

Incineration The burning of solid waste is called **incineration** (in sin ur AY shun). Incineration has some advantages. The burning facilities, or incinerators, do not take up much space. They do not pose a risk of polluting groundwater. The heat produced by burning solid waste can be used to generate electricity. These "waste-to-energy" plants supply electricity to many homes in the United States.

Unfortunately, incinerators do have drawbacks. Even the best incinerators release some pollution into the air. And although incinerators reduce the volume of waste by as much as 90 percent, some waste still remains. This waste needs to be disposed of somewhere. Finally, incinerators are expensive to build.

FIGURE 16
Waste Disposal
Billions of tons of municipal solid waste are created in the United States each year. More than one third of that waste is paper.
Reading Graphs *What percentage of solid waste does food waste represent?*

Landfills Until fairly recently, people usually disposed of waste in open holes in the ground. But these open dumps were dangerous and unsightly. Rainwater falling on a dump dissolved chemicals from the wastes, forming a polluted liquid called **leachate.** Leachate could run off into streams and lakes, or trickle down into the groundwater below the dump.

In 1976, the government banned open dumps. Now much solid waste is buried in landfills that are constructed to hold the wastes more safely. A **sanitary landfill** holds municipal solid waste, construction debris, and some types of agricultural and industrial waste. Figure 17 shows the parts of a well-designed sanitary landfill. Once a landfill is full, it is covered with a clay cap to keep rainwater from entering the waste.

However, even well-designed landfills still pose a risk of polluting groundwater. And while capped landfills can be reused in certain ways, including as parks and sites for sports arenas, they cannot be used for housing or agriculture.

Reading Checkpoint **What are two possible uses of a capped sanitary landfill?**

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For: Sanitary Landfill activity
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FIGURE 17
Sanitary Landfill
A well-designed sanitary landfill contains the waste and prevents it from polluting the surrounding land and water.

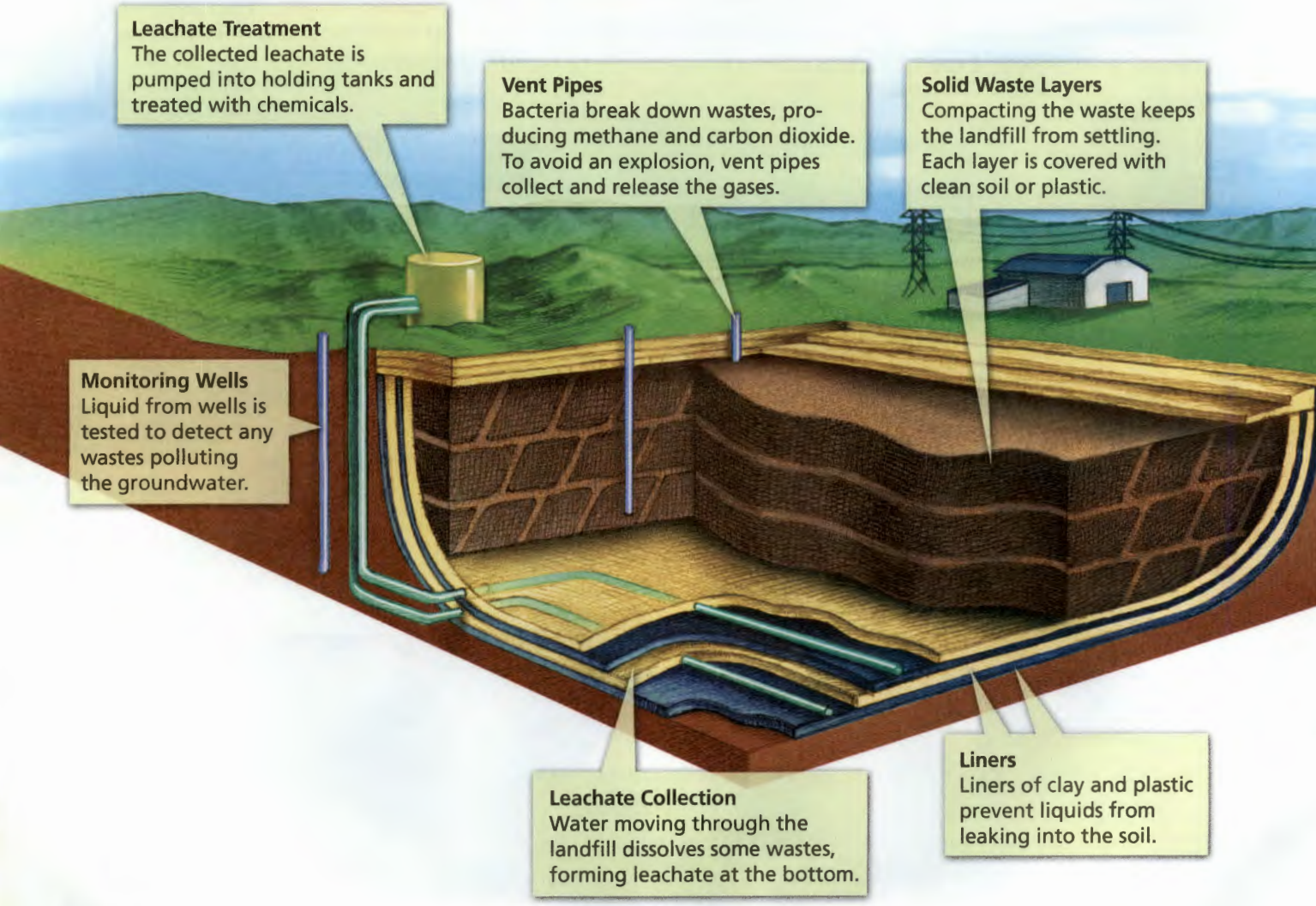


FIGURE 18
Metal Recycling
Metal is a commonly recycled material. Here, crumpled aluminum cans ride up a conveyor belt in a recycling center.
Predicting *Without recycling, what might eventually happen to the supply of aluminum?*

Recycling

The process of reclaiming raw materials and reusing them to create new products is called **recycling.** Recycling reduces the volume of solid waste by enabling people to use the materials in wastes again. While recycling uses some energy, it also saves the energy that would be needed to obtain and process raw materials.

As you know, matter in ecosystems is naturally recycled through the water cycle, carbon cycle, and other processes. Any material that can be broken down and recycled by bacteria and other decomposers is **biodegradable** (by oh dih GRAY duh bul). Unfortunately, many of the products people use today are not biodegradable. Plastic containers, metal cans, rubber tires, and glass jars are examples of products that do not naturally decompose. Instead, people have developed techniques to recycle the raw materials in these products.

A wide range of materials, including motor oil, tires, and batteries, can be recycled. Most recycling focuses on four major categories of products: metal, plastic, glass, and paper.

Metal In your classroom, you are surrounded by metal objects that can be recycled. Your desk, scissors, staples, and paper clips are probably made of steel. Another very common metal, aluminum, is used to make soda cans, house siding, window screens, and many other products.

Metals such as iron and aluminum can be recycled. Recycling metal saves money and causes less pollution than making new metal. With recycling, no ore needs to be mined, transported to factories, or processed. In addition, recycling metals helps conserve these nonrenewable resources.

Lab zone Skills Activity

Graphing

What happens to trash? Use the data in the table below to construct a circle graph of methods of municipal solid waste disposal in the United States. Give your circle graph a title. (For help making a circle graph, see the Skills Handbook.)

Method of Disposal	Percentage of Waste
Landfills	56%
Recycling	27%
Incineration	17%

FIGURE 19
Plastic Recycling
Plastic bottles can be recycled and made into many products, including polyester fleece for jackets.

Plastic When oil is refined to make gasoline and other petroleum products, solid materials called resins are left over. Resins can be heated, stretched, and molded into plastic products. Common plastic products that can easily be recycled include milk jugs, detergent containers, and soda bottles. When these products are recycled, they take on very different forms: as fleece jackets, carpeting, floor tiles, trash cans, or even dock pilings!

Glass Glass is made from sand, soda ash, and limestone mixed together and heated. Glass is one of the easiest products to recycle because glass pieces can be melted down over and over to make new glass containers.

Recycling glass is less expensive than making glass from raw materials. Because the recycled pieces melt at a lower temperature than the raw materials, less energy is required. Recycling glass also reduces the environmental damage caused by mining for soda and limestone.

Paper It takes about 17 trees to make one metric ton of paper. Paper mills turn wood into a thick liquid called pulp. Pulp is spread out and dried to produce paper. Pulp can also be made from old newspapers and old used paper. Most paper products can only be recycled a few times. Each time paper is recycled, the new paper is rougher, weaker, and darker.

Is Recycling Worthwhile? Besides conserving resources, recycling also saves energy. For example, making aluminum products from recycled aluminum rather than from raw materials uses about 90 percent less energy overall. For certain materials, recycling is usually worthwhile.

But recycling is not a complete answer to the solid waste problem. For some cities, recycling is not cost-effective. Scientists have not found good ways to recycle some materials. The value of recycling must be judged on a case-by-case basis.

Lab zone Try This **Activity**

It's in the Numbers

Plastic bottles and other plastic products usually have a number inside a triangle indicating the type of plastic they are made of. Plastics must be sorted by type before they can be recycled.

Sort the plastic products your teacher gives you into groups according to their recycling numbers.

Classifying Compare and contrast the pieces in each group with one another and with the pieces in other groups. Describe the characteristics of each group.

What People Can Do

The good news is that there are ways individuals can help control the solid waste problem. **These are sometimes called the "three R's"—reduce, reuse, and recycle.** *Reduce* refers to creating less waste in the first place. For example, you can use a cloth shopping bag rather than a disposable paper or plastic bag. *Reuse* refers to finding another use for an object rather than discarding it. For example, you could refill plastic drink bottles with drinking water instead of buying new bottles of water.

As you have read, *recycle* refers to reclaiming raw materials to create new products. You can take the first step in the recycling process by recycling at home and by encouraging others to recycle. You can also make an effort to buy products made from recycled materials. This encourages companies to use recycled materials in their products.

Another way to reduce the amount of solid waste your family produces is to start a compost pile. **Composting** is the process of helping biodegradable wastes to decompose naturally. The moist, dark conditions in a compost pile allow natural decomposers to break down waste more quickly. Compost piles can be used to recycle grass clippings, raked leaves, and some food wastes. Compost is an excellent natural fertilizer for plants.

FIGURE 20
Composting
Many kinds of food and yard waste can be composted.
Interpreting Photographs *How does composting help reduce household waste?*

Reading Checkpoint **What is composting?**

Section 5 Assessment

S 6.6.c, E-LA: Reading 6.1.0

Vocabulary Skill **Prefixes** Use what you know about the prefix *bio-* to help you define the word *biodegradable.*

Reviewing Key Concepts

1. a. **Reviewing** Name three ways of dealing with solid waste.
   b. **Comparing and Contrasting** Describe an advantage and a disadvantage of each method.
   c. **Developing Hypotheses** Near a former open dump, there is a stream in which your older relatives used to fish. No one fishes there anymore, however, because there are no fish. What might have happened?
2. a. **Identifying** What is meant by the "three R's"?
   b. **Problem Solving** Give one example of how you could practice each of the "three R's."

Lab zone At-Home Activity

Trash Weigh-In For one week, have your family collect its household trash in large bags. Do not include food waste. At the end of the week, hold a trash weigh-in. Multiply the total amount by 52 to show how much trash your family produces in a year. Can you come up with any ways to reduce your family trash load?

Chapter 12 Study Guide

The BIG Idea

Energy and material resources differ in a variety of ways, including their costs, availability of supplies, and environmental impacts to produce and use.

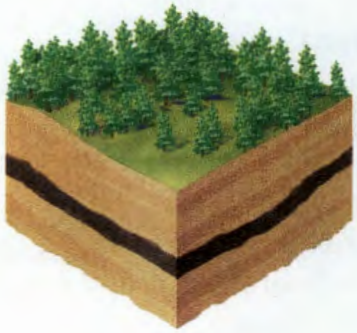
1 Fossil Fuels

Key Concepts — S 6.3.b, 6.6.a

- When fuels are burned, the chemical energy that is released can be used to generate another form of energy, such as heat, light, motion, or electricity.
- The three major fossil fuels are coal, oil, and natural gas.
- Since fossil fuels take hundreds of millions of years to form, they are considered nonrenewable resources.

Key Terms

fuel
energy transformation
combustion
fossil fuel
hydrocarbon
petroleum
refinery
petrochemical



2 Renewable Sources of Energy

Key Concepts — S 6.6.a, 6.6.b

- The sun constantly gives off energy in the forms of light and heat.
- In addition to solar energy, renewable sources of energy include water, the wind, biomass fuels, geothermal energy, and the tides.

Key Terms

solar energy
hydroelectric power
biomass fuel
gasohol
geothermal energy
tide

3 Nuclear Energy

Key Concepts — S 6.6.a, 6.6.b

- During nuclear fission, the nucleus splits apart into smaller nuclei and two or more neutrons.
- In a nuclear power plant, the heat released from fission reactions is used to change water into steam. The steam then turns the blades of a turbine to generate electricity.
- In nuclear fusion, two hydrogen nuclei combine to create a helium nucleus, which has slightly less mass than the two hydrogen nuclei. The lost mass is converted to energy.

Key Terms

nucleus
nuclear fission
reactor vessel
fuel rod
control rod
meltdown
nuclear fusion

4 Energy Conservation

Key Concepts — S 6.3.a, 6.3.b

- One way to preserve energy resources is to increase the efficiency of energy use. Another way is to conserve energy whenever possible.

Key Terms

• efficiency • insulation • energy conservation

5 Waste Disposal and Recycling

Key Concepts — S 6.6.c

- Three methods of handling solid waste are burning, burying, and recycling. Each method has advantages and disadvantages.
- One way to help solve the solid waste problem is to practice the "three R's"—reduce, reuse, and recycle.

Key Terms

• municipal solid waste • incineration
• leachate • sanitary landfill • recycling
• biodegradable • composting

Review and Assessment

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Target Reading Skill

Compare and Contrast The table compares and contrasts various sources of energy. Copy the table onto a separate sheet of paper and then complete it.

Sources of Energy		
Energy Type	**Advantages**	**Disadvantages**
Coal	Low cost, plentiful	
Oil		Nonrenewable, mostly imported
Solar		
Wind		
Hydroelectric		
Geothermal		
Nuclear fission		
Nuclear fusion		

Reviewing Key Terms

Choose the letter of the best answer.

1. Which of the following is *not* a fossil fuel?
   a. coal
   b. wood
   c. oil
   d. natural gas
2. Wind and biomass energy are both indirect forms of
   a. nuclear energy.
   b. electrical energy.
   c. solar energy.
   d. geothermal energy.
3. The particle used to start a nuclear fission reaction is a(n)
   a. neutron. **b.** electron.
   c. proton. **d.** atom.
4. The part of a nuclear power plant where fission takes place is the
   a. turbine. **b.** control rod.
   c. heat exchanger. **d.** reactor vessel.
5. The process of reclaiming raw materials and reusing them to create new products is called
   a. incineration. **b.** recycling.
   c. composting. **d.** combustion.

Complete the following sentences so that your answers clearly explain the key terms.

6. In the process of **combustion,** a fuel such as coal undergoes _____.
7. Gasoline is a **petrochemical,** which means it is a(n) _____.
8. **Geothermal energy** is a renewable energy source that is produced from _____.
9. **Energy conservation** means that _____ .
10. **Composting** is a process in which _____.

Writing in Science

Letter In a letter to a friend, predict how solar energy will change your life over the next 20 years. Include specific details in your description.

Video Assessment
Discovery Channel School
Energy Resources

Review and Assessment

Checking Concepts

11. Describe how coal forms.
12. What is natural gas? How is natural gas transported to where it is needed?
13. Describe three features of a solar home. (Your answer may include passive and active solar systems.)
14. Explain how wind can be used to generate electricity.
15. How is a nuclear fission reaction controlled in a nuclear reactor?
16. Define energy efficiency. Give three examples of inventions that increase energy efficiency.
17. Name and define the "three R's" of solid waste management.

Thinking Critically

18. **Comparing and Contrasting** Compare the recycling of metal and paper. How are they similar? How are they different?
19. **Predicting** Do you think you will ever live in a solar house? Support your prediction with details about the climate in your area.
20. **Classifying** State whether each of the following energy sources is renewable or nonrenewable: coal, solar power, natural gas, hydroelectric power. Give a reason for each answer.
21. **Making Judgments** Write a short paragraph explaining why you agree or disagree with the following statement: "The United States should build more nuclear power plants to prepare for the future shortage of fossil fuels."
22. **Relating Cause and Effect** In the nuclear reaction shown below, a neutron is about to strike a U-235 nucleus. What will happen next?

Applying Skills

Use the information in the table to answer Questions 23–27.

The table below shows the world's energy production in 1973 and today.

Energy Source	Units Produced 1973	Units Produced Today
Oil	2,861	3,574
Natural gas	1,226	2,586
Coal	2,238	3,833
Nuclear	203	2,592
Hydroelectric	1,300	2,705
Total	7,828	15,290

23. **Interpreting Data** How did the total energy production change from 1973 to today?
24. **Calculating** What percentage of the total world energy production did nuclear power provide in 1973? What percentage does it provide today?
25. **Classifying** Classify the different energy sources according to whether they are renewable or nonrenewable.
26. **Inferring** How has the importance of hydroelectric power changed from 1973 to the present?
27. **Predicting** How do you think the world's energy production will change over the next 40 years? Explain.

Lab zone Standards Investigation

Performance Assessment Share your energy-audit report with another group. The group should review the report for clarity, organization, and detail. Make revisions based on feedback from the other group. As a class, discuss each group's findings. Then prepare a class proposal with the best suggestions for conserving energy in your school.

Choose the letter of the best answer.

1. When a fuel is consumed, most of the energy released eventually ends up as
   A light.
   B sound.
   C heat.
   D electricity. **S 6.3.b**

2. Many plastics and paints are made from
   A gasohol.
   B biomass.
   C uranium.
   D petrochemicals. **S 6.6.c**

3. The interior of your car heats up on a sunny day because of
   A passive solar heating.
   B solar cells.
   C active solar heating.
   D indirect solar heating. **S 6.6.a**

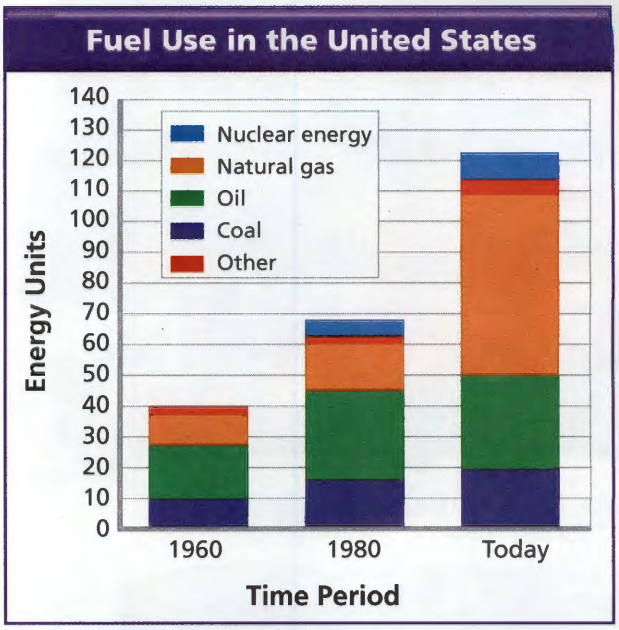
4. The main function of a dam in producing electricity is to
   A form a reservoir for recreation.
   B prevent flooding after a heavy rain.
   C provide a source of fast-moving water.
   D provide a source of wind. **S 6.6.a**

5. Which of the following steps in producing electricity in a nuclear reactor comes first?
   A Steam turns the blades of a turbine.
   B Water boils to produce steam.
   C Uranium atoms are split.
   D Heat is released. **S 6.6.a**

6. Heat flow from a warm house to the cold outdoors can be reduced by
   A insulation.
   B combustion.
   C recycling.
   D incineration. **S 6.3.a**

7. Which of the following is a renewable energy source?
   A oil
   B coal
   C wind
   D natural gas **S 6.6.b**

Use the graph to answer Questions 8 and 9.



8. According to the graph, most of the fuel sources used in the United States today are
   A renewable fuels.
   B nuclear fuels.
   C fossil fuels.
   D solar energy. **S 6.6.a, 6.6.b**

9. Which statement about fuel use in the United States is best supported by the graph?
   A Natural gas has become the most widely used fuel source.
   B The use of nuclear energy is decreasing.
   C Coal is becoming the main source of fuel.
   D The amount of oil being used today has greatly decreased since 1980. **S 6.6.a**

Apply the BIG Idea

10. State two advantages and two disadvantages of using coal to generate electricity. Do the same for using solar energy to produce electricity. Classify each as either a renewable or nonrenewable energy resource. Explain your reasoning in each case. **S 6.6.a, 6.6.b**

Ecology and Resources

Unit 4 Review

Chapter 10
Ecosystems

The BIG Idea

Organisms in ecosystems exchange energy and nutrients among themselves and with the environment.

- What needs are met by an organism's environment?
- How does energy move through an ecosystem?
- What are the major ways in which organisms in an ecosystem interact?

Chapter 11
Living Resources

The BIG Idea

The environment defines the characteristics and ecological roles of the organisms found in different biomes. Therefore, similar biomes may contain organisms that play similar ecological roles.

- What are the characteristic organisms of the six major biomes?
- How can forests be managed as renewable resources?
- What factors affect an area's biodiversity?

Chapter 12
Energy and Material Resources

The BIG Idea

Energy and material resources differ in a variety of ways, including their costs, availability of supplies, and environmental impacts to produce and use.

- Why are fossil fuels considered nonrenewable resources?
- What are some renewable sources of energy?

Unit 4 Assessment

Connecting the BIG Ideas

Power Plant Choices			
Type of Power Plant	Advantage/ Disadvantage	Renewable/ Nonrenewable	Effects on Ecosystem
Coal			
Wind			
Nuclear			

A small city at the edge of California's Central Valley is growing quickly. The council must choose either a coal, wind, or nuclear power plant to meet the increasing energy demands. An expert on energy resources and an ecologist give the council advice.

The energy expert says that although a coal power plant will be expensive, coal is a relatively cheap fuel. She also says that the plant will cause some air pollution.

Next, she explains that wind energy will not pollute the air. In addition, the cost of power produced by wind turbines is about the same as that of the coal plant. However, dozens of wind turbines would have to be built.

Finally, the energy expert says that a nuclear power plant is expensive, but will not pollute the air. However, radioactive waste must be disposed of safely. Also, the water used to cool the plant will be warm when released back into the environment.

The ecologist explains that a nearby river flows through a marsh that floods in winter. The marsh is home to many fish, insects, amphibians, migrating birds, and mammals. Grasses, tall rushes, and shrubs cover the marsh. Large trees line the riverbanks.

The ecologist suggests that pollution from a coal power plant could make the water more acidic and injure marsh organisms. The wind turbines might kill migrating birds. Warm water from a nuclear plant may harm some animals, but could benefit others.

1. Which organisms are the primary producers in the marsh? *(Chapter 10)*
a. birds
b. amphibians and mammals
c. insects
d. grasses, rushes, and shrubs

2. To which biome do the freshwater marshes of the Central Valley belong? *(Chapter 11)*
a. deciduous **b.** tundra
c. grassland **d.** temperate rain forest

3. Which type of power plant considered by the city council uses renewable energy? *(Chapter 12)*
a. coal **b.** wind
c. natural gas **d.** oil

4. **Summary** Summarize the three power plant choices. Include the advantages and disadvantages of each type of power plant, whether the energy source is renewable or nonrenewable, and how it may affect the marsh ecosystem.