

Energy and Energy Resources

chapter preview

sections

- 1 What is energy?
 - 2 Energy Transformations
Lab *Hearing with Your Jaw*
 - 3 Sources of Energy
Lab *Energy to Power Your Life*
-  **Virtual Lab** *What are the relationships between kinetic energy and potential energy?*

Blowing Off Steam

The electrical energy you used today might have been produced by a coal-burning power plant like this one. Energy contained in coal is transformed into heat, and then into electrical energy. As boiling water heated by the burning coal is cooled, steam rises from these cone-shaped cooling towers.

Science Journal Choose three devices that use electricity, and identify the function of each device.

Start-Up Activities



Marbles and Energy

What's the difference between a moving marble and one at rest? A moving marble can hit something and cause a change to occur. How can a marble acquire energy—the ability to cause change? 

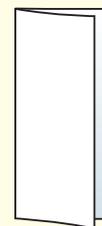


1. Make a track on a table by slightly separating two metersticks placed side by side.
2. Using a book, raise one end of the track slightly and measure the height.
3. Roll a marble down the track. Measure the distance from its starting point to where it hits the floor. Repeat. Calculate the average of the two measurements.
4. Repeat steps 2 and 3 for three different heights. Predict what will happen if you use a heavier marble. Test your prediction and record your observations.
5. **Think Critically** In your Science Journal, describe how the distance traveled by the marble is related to the height of the ramp. How is the motion of the marble related to the ramp height?

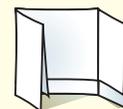
FOLDABLES™ Study Organizer

Energy Make the following Foldable to help identify what you already know, what you want to know, and what you learned about energy.

STEP 1 **Fold** a vertical sheet of paper from side to side. Make the front edge about 1 cm shorter than the back edge.



STEP 2 **Turn** lengthwise and **fold** into thirds



STEP 3 **Unfold, cut, and label** each tab for only the top layer along both folds to make three tabs.



Identify Questions Before you read the chapter, write what you know and what you want to know about the types, sources, and transformation of energy under the appropriate tabs. As you read the chapter, correct what you have written and add more questions under the *Learned* tab.



Preview this chapter's content and activities at bookm.msscience.com

What is energy?

as you read

What You'll Learn

- **Explain** what energy is.
- **Distinguish** between kinetic energy and potential energy.
- **Identify** the various forms of energy.

Why It's Important

Energy is involved whenever a change occurs.

Review Vocabulary

mass: a measure of the amount of matter in an object

New Vocabulary

- energy
- kinetic energy
- potential energy
- thermal energy
- chemical energy
- radiant energy
- electrical energy
- nuclear energy

The Nature of Energy

What comes to mind when you hear the word *energy*? Do you picture running, leaping, and spinning like a dancer or a gymnast? How would you define energy? When an object has energy, it can make things happen. In other words, **energy** is the ability to cause change. What do the items shown in **Figure 1** have in common?

Look around and notice the changes that are occurring—someone walking by or a ray of sunshine that is streaming through the window and warming your desk. Maybe you can see the wind moving the leaves on a tree. What changes are occurring?

Transferring Energy You might not realize it, but you have a large amount of energy. In fact, everything around you has energy, but you notice it only when a change takes place. Anytime a change occurs, energy is transferred from one object to another. You hear a footstep because energy is transferred from a foot hitting the ground to your ears. Leaves are put into motion when energy in the moving wind is transferred to them. The spot on the desktop becomes warmer when energy is transferred to it from the sunlight. In fact, all objects, including leaves and desktops, have energy.

Figure 1 Energy is the ability to cause change. **Explain** how these objects cause change.



Energy of Motion

Things that move can cause change. A bowling ball rolls down the alley and knocks down some pins, as in **Figure 2A**. Is energy involved? A change occurs when the pins fall over. The bowling ball causes this change, so the bowling ball has energy. The energy in the motion of the bowling ball causes the pins to fall. As the ball moves, it has a form of energy called kinetic energy. **Kinetic energy** is the energy an object has due to its motion. If an object isn't moving, it doesn't have kinetic energy.

Kinetic Energy and Speed If you roll the bowling ball so it moves faster, what happens when it hits the pins? It might knock down more pins, or it might cause the pins to go flying farther. A faster ball causes more change to occur than a ball that is moving slowly. Look at **Figure 2B**. The professional bowler rolls a fast-moving bowling ball. When her ball hits the pins, pins go flying faster and farther than for a slower-moving ball. All that action signals that her ball has more energy. The faster the ball goes, the more kinetic energy it has. This is true for all moving objects. Kinetic energy increases as an object moves faster.

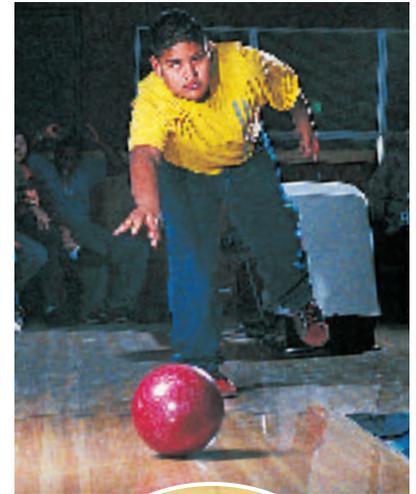
 **Reading Check** *How does kinetic energy depend on speed?*

Kinetic Energy and Mass Suppose, as shown in **Figure 2C**, you roll a volleyball down the alley instead of a bowling ball. If the volleyball travels at the same speed as a bowling ball, do you think it will send pins flying as far? The answer is no. The volleyball might not knock down any pins. Does the volleyball have less energy than the bowling ball even though they are traveling at the same speed?

An important difference between the volleyball and the bowling ball is that the volleyball has less mass. Even though the volleyball is moving at the same speed as the bowling ball, the volleyball has less kinetic energy because it has less mass. Kinetic energy also depends on the mass of a moving object. Kinetic energy increases as the mass of the object increases.

Figure 2 The kinetic energy of an object depends on the mass and speed of the object.

A This ball has kinetic energy because it is rolling down the alley.



B This ball has more kinetic energy because it has more speed.



C This ball has less kinetic energy because it has less mass.



Figure 3 The potential energy of an object depends on its mass and height above the ground.

Determine which vase has more potential energy, the red one or the blue one.



Energy of Position

An object can have energy even though it is not moving. For example, a glass of water sitting on the kitchen table doesn't have any kinetic energy because it isn't moving. If you accidentally nudge the glass and it falls on the floor, changes occur. Gravity pulls the glass downward, and the glass has energy of motion as it falls. Where did this energy come from?

When the glass was sitting on the table, it had potential (puh TEN chul) energy. **Potential energy** is the energy stored in an object because of its position. In this case, the position is the height of the glass above the floor. The potential energy of the glass changes to kinetic energy as the glass falls. The potential energy of the glass is greater if it is higher above the floor. Potential energy

also depends on mass. The more mass an object has, the more potential energy it has. Which object in **Figure 3** has the most potential energy?

Forms of Energy

Food, sunlight, and wind have energy, yet they seem different because they contain different forms of energy. Food and sunlight contain forms of energy different from the kinetic energy in the motion of the wind. The warmth you feel from sunlight is another type of energy that is different from the energy of motion or position.

Thermal Energy The feeling of warmth from sunlight signals that your body is acquiring more thermal energy. All objects have **thermal energy** that increases as its temperature increases. A cup of hot chocolate has more thermal energy than

a cup of cold water, as shown in **Figure 4**. Similarly, the cup of water has more thermal energy than a block of ice of the same mass. Your body continually produces thermal energy. Many chemical reactions that take place inside your cells produce thermal energy. Where does this energy come from? Thermal energy released by chemical reactions comes from another form of energy called chemical energy.

Figure 4 The hotter an object is, the more thermal energy it has. A cup of hot chocolate has more thermal energy than a cup of cold water, which has more thermal energy than a block of ice with the same mass.



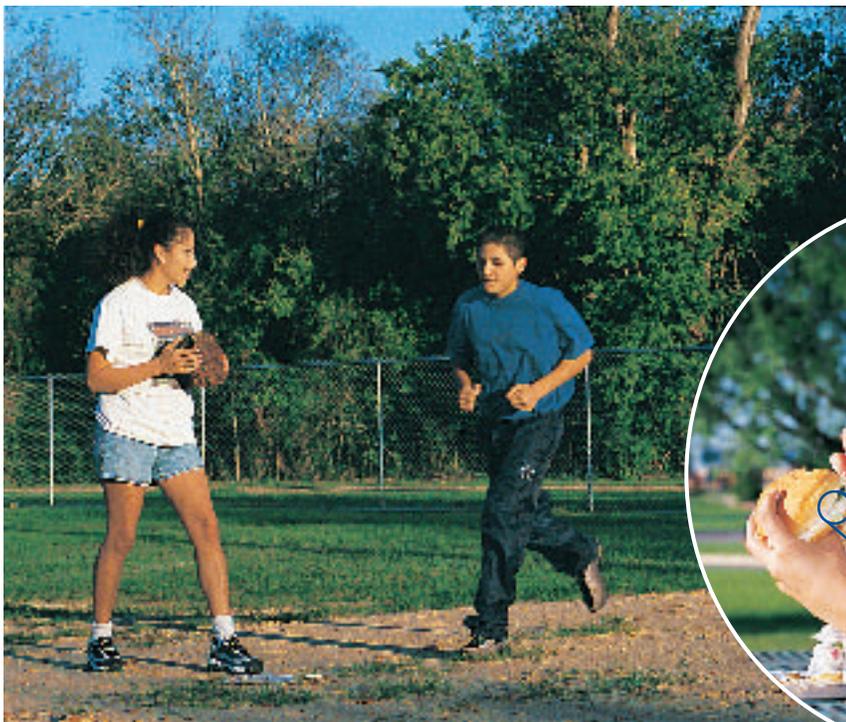


Figure 5 Complex chemicals in food store chemical energy. During activity, the chemical energy transforms into kinetic energy.

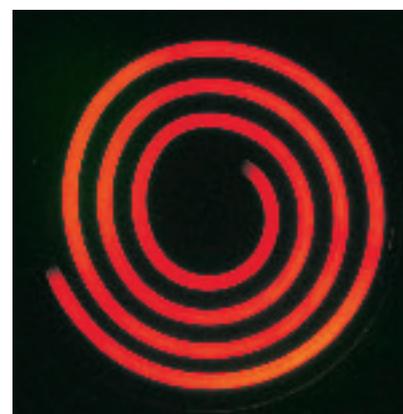


Chemical Energy When you eat a meal, you are putting a source of energy inside your body. Food contains chemical energy that your body uses to provide energy for your brain, to power your movements, and to fuel your growth. As in **Figure 5**, food contains chemicals, such as sugar, which can be broken down in your body. These chemicals are made of atoms that are bonded together, and energy is stored in the bonds between atoms. **Chemical energy** is the energy stored in chemical bonds. When chemicals are broken apart and new chemicals are formed, some of this energy is released. The flame of a candle is the result of chemical energy stored in the wax. When the wax burns, chemical energy is transformed into thermal energy and light energy.

 **Reading Check** *When is chemical energy released?*

Light Energy Light from the candle flame travels through the air at an incredibly fast speed of 300,000 km/s. This is fast enough to circle Earth almost eight times in 1 s. When light strikes something, it can be absorbed, transmitted, or reflected. When the light is absorbed by an object, the object can become warmer. The object absorbs energy from the light and this energy is transformed into thermal energy. Then energy carried by light is called **radiant energy**. **Figure 6** shows a coil of wire that produces radiant energy when it is heated. To heat the metal, another type of energy can be used—electrical energy.

Figure 6 Electrical energy is transformed into thermal energy in the metal heating coil. As the metal becomes hotter, it emits more radiant energy.





Electrical Energy Electrical lighting is one of the many ways electrical energy is used. Look around at all the devices that use electricity. Electric current flows in these devices when they are connected to batteries or plugged into an electric outlet. **Electrical energy** is the energy that is carried by an electric current. An electric device uses the electrical energy provided by the current flowing in the device. Large electric power plants generate the enormous amounts of electrical energy used each day. About 20 percent of the electrical energy used in the United States is generated by nuclear power plants.

Figure 7 Complex power plants are required to obtain useful energy from the nucleus of an atom.

Nuclear Energy Nuclear power plants use the energy stored in the nucleus of an atom to generate electricity. Every atomic nucleus contains energy—**nuclear energy**—that can be transformed into other forms of energy. However, releasing the nuclear energy is a difficult process. It involves the construction of complex power plants, shown in **Figure 7**. In contrast, all that is needed to release chemical energy from wood is a lighted match.

section 1 review

Summary

The Nature of Energy

- Energy is the ability to cause change.
- Kinetic energy is the energy an object has due to its motion. Kinetic energy depends on an object's speed and mass.
- Potential energy is the energy an object has due to its position. Potential energy depends on an object's height and mass.

Forces of Energy

- Thermal energy increases as temperature increases.
- Chemical energy is the energy stored in chemical bonds in molecules.
- Light energy, also called radiant energy, is the energy contained in light.
- Electrical energy is the energy carried by electric current.
- Nuclear energy is the energy contained in the nucleus of an atom.

Self Check

1. **Explain** why a high-speed collision between two cars would cause more damage than a low-speed collision between the same two cars.
2. **Describe** the energy transformations that occur when a piece of wood is burned.
3. **Identify** the form of energy that is converted into thermal energy by your body.
4. **Explain** how, if two vases are side by side on a shelf, one could have more potential energy.
5. **Think Critically** A golf ball and a bowling ball are moving and both have the same kinetic energy. Which one is moving faster? If they move at the same speed, which one has more kinetic energy?

Applying Skills

6. **Communicate** In your Science Journal, record different ways the word *energy* is used. Which ways of using the word *energy* are closest to the definition of energy given in this section?

Energy Transformations

Changing Forms of Energy

Chemical, thermal, radiant, and electrical are some of the forms that energy can have. In the world around you, energy is transforming continually between one form and another. You observe some of these transformations by noticing a change in your environment. Forest fires are a dramatic example of an environmental change that can occur naturally as a result of lightning strikes. A number of changes occur that involve energy as the mountain biker in **Figure 8** pedals up a hill. What energy transformations cause these changes to occur?

Tracking Energy Transformations As the mountain biker pedals, his leg muscles transform chemical energy into kinetic energy. The kinetic energy of his leg muscles transforms into kinetic energy of the bicycle as he pedals. Some of this energy transforms into potential energy as he moves up the hill. Also, some energy is transformed into thermal energy. His body is warmer because chemical energy is being released. Because of friction, the mechanical parts of the bicycle are warmer, too. Energy in the form of heat is almost always one of the products of an energy transformation. The energy transformations that occur when people exercise, when cars run, when living things grow and even when stars explode, all produce heat.

as you read

What You'll Learn

- **Apply** the law of conservation of energy to energy transformations.
- **Identify** how energy changes form.
- **Describe** how electric power plants produce energy.

Why It's Important

Changing energy from one form to another is what makes cars run, furnaces heat, telephones work, and plants grow.



Review Vocabulary

transformation: a change in composition or structure

New Vocabulary

- law of conservation of energy
- generator
- turbine

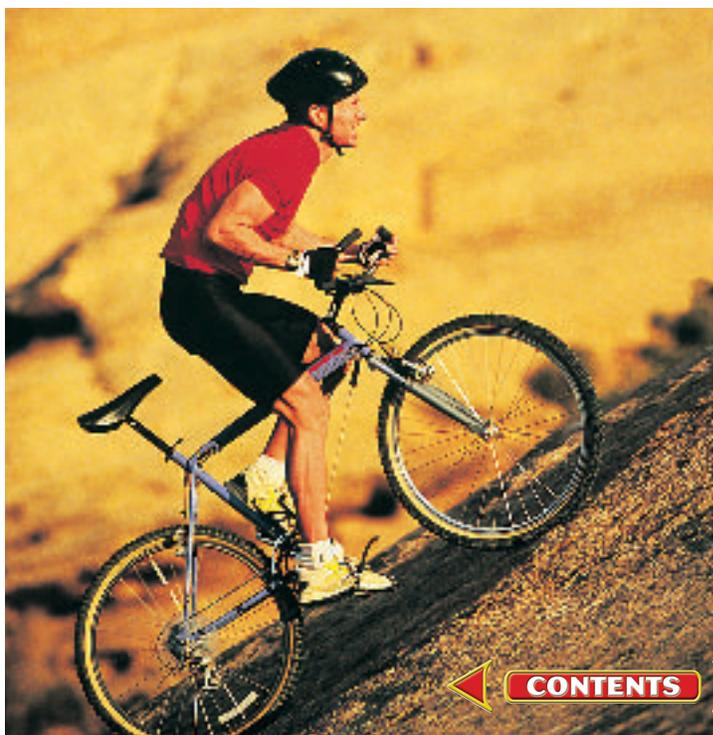


Figure 8 The ability to transform energy allows the biker to climb the hill.

Identify all the forms of energy that are represented in the photograph.

Topic: Energy Transformations

Visit bookm.msscience.com for Web links to information about energy transformations that occur during different activities and processes.

Activity Choose an activity or process and make a graph showing how the kinetic and potential energy change during it.

The Law of Conservation of Energy

It can be a challenge to track energy as it moves from object to object. However, one extremely important principle can serve as a guide as you trace the flow of energy. According to the **law of conservation of energy**, energy is never created or destroyed. The only thing that changes is the form in which energy appears. When the biker is resting at the summit, all his original energy is still around. Some of the energy is in the form of potential energy, which he will use as he coasts down the hill. Some of this energy was changed to thermal energy by friction in the bike. Chemical energy was also changed to thermal energy in the biker's muscles, making him feel hot. As he rests, this thermal energy moves from his body to the air around him. No energy is missing—it can all be accounted for.

 **Reading Check** *Can energy ever be lost? Why or why not?*

Changing Kinetic and Potential Energy

The law of conservation of energy can be used to identify the energy changes in a system. For example, tossing a ball into the air and catching it is a simple system. As shown in **Figure 9**, as the ball leaves your hand, most of its energy is kinetic. As the ball rises, it slows and its kinetic energy decreases. But, the total energy of the ball hasn't changed. The decrease in kinetic energy equals the increase in potential energy as the ball flies higher in the air. The total amount of energy remains constant. Energy moves from place to place and changes form, but it never is created or destroyed.

Figure 9 During the flight of the baseball, energy is transforming between kinetic and potential energy.

Determine where the ball has the most kinetic energy. Where does the ball have the most total energy?

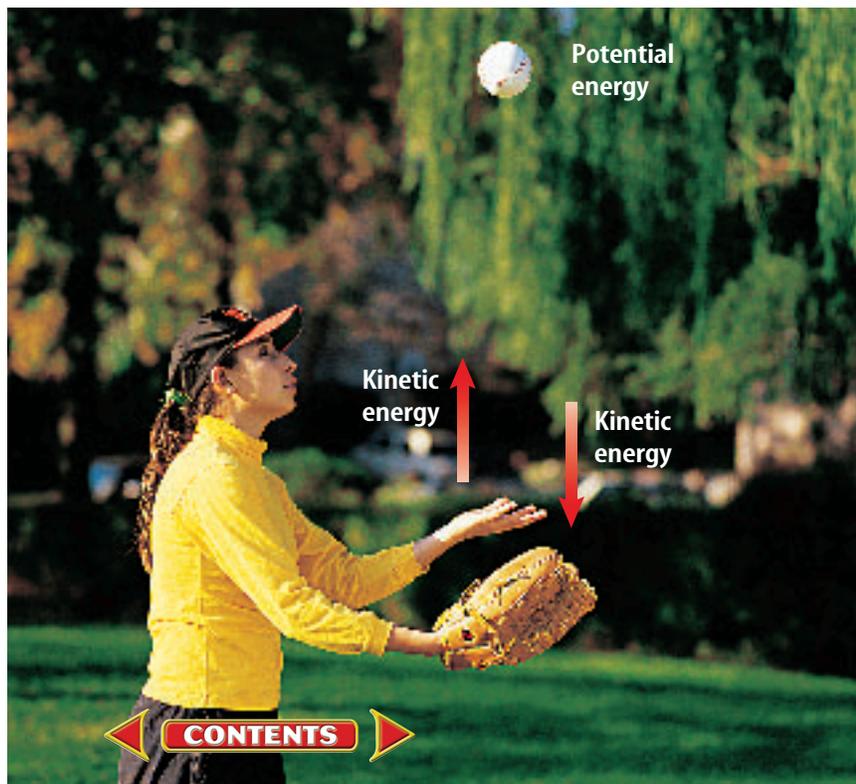
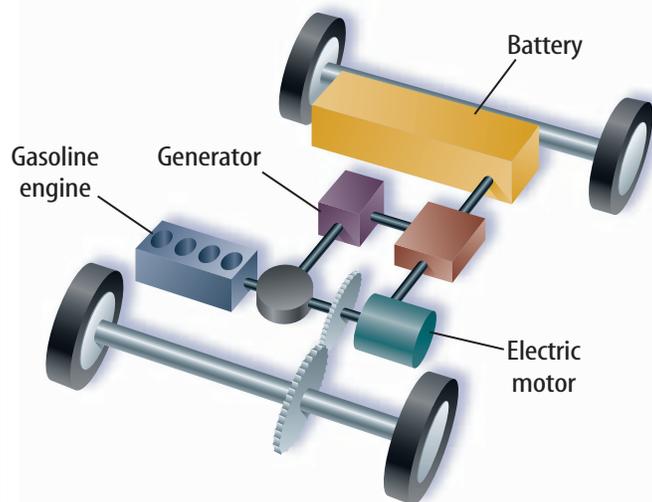


Figure 10 Hybrid cars that use an electric motor and a gasoline engine for power are now available. Hybrid cars make energy transformations more efficient.



Energy Changes Form

Energy transformations occur constantly all around you. Many machines are devices that transform energy from one form to another. For example, an automobile engine transforms the chemical energy in gasoline into energy of motion. However, not all of the chemical energy is converted into kinetic energy. Instead, some of the chemical energy is converted into thermal energy, and the engine becomes hot. An engine that converts chemical energy into more kinetic energy is a more efficient engine. New types of cars, like the one shown in **Figure 10**, use an electric motor along with a gasoline engine. These engines are more efficient so the car can travel farther on a gallon of gas.



Transforming Chemical Energy

Inside your body, chemical energy also is transformed into kinetic energy. Look at **Figure 11**. The transformation of chemical to kinetic energy occurs in muscle cells. There, chemical reactions take place that cause certain molecules to change shape. Your muscle contracts when many of these changes occur, and a part of your body moves.

The matter contained in living organisms, also called biomass, contains chemical energy. When organisms die, chemical compounds in their biomass break down. Bacteria, fungi, and other organisms help convert these chemical compounds to simpler chemicals that can be used by other living things.

Thermal energy also is released as these changes occur. For example, a compost pile can contain plant matter, such as grass clippings and leaves. As the compost pile decomposes, chemical energy is converted into thermal energy. This can cause the temperature of a compost pile to reach 60°C.

Mini LAB

Analyzing Energy Transformations

Procedure

1. Place soft **clay** on the floor and smooth out its surface.
2. Hold a **marble** 1.5 m above the clay and drop it. Measure the depth of the crater made by the marble.
3. Repeat this procedure using a **golf ball** and a **plastic golf ball**.

Analysis

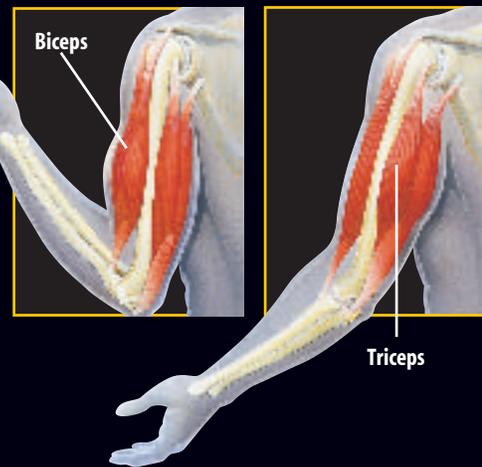
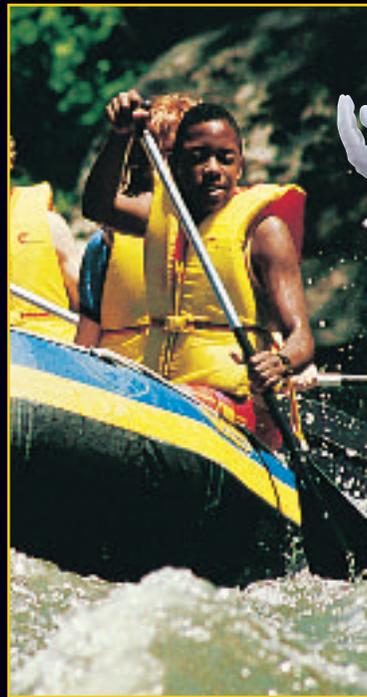
1. Compare the depths of the craters to determine which ball had the most kinetic energy as it hit the clay.
2. Explain how potential energy was transformed into kinetic energy during your activity.



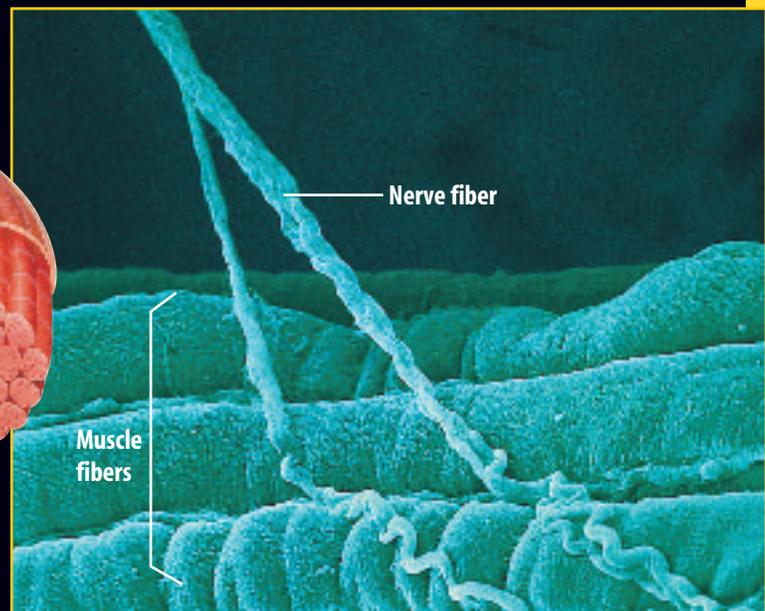
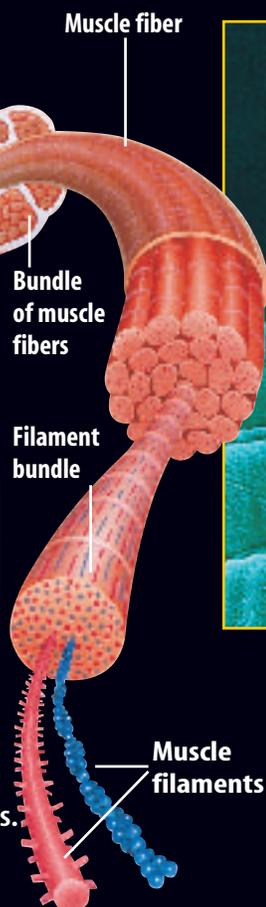
Figure 11

Paddling a raft, throwing a baseball, playing the violin — your skeletal muscles make these and countless other body movements possible. Muscles work by pulling, or contracting. At the cellular level, muscle contractions are powered by reactions that transform chemical energy into kinetic energy.

▶ Energy transformations taking place in your muscles provide the power to move.



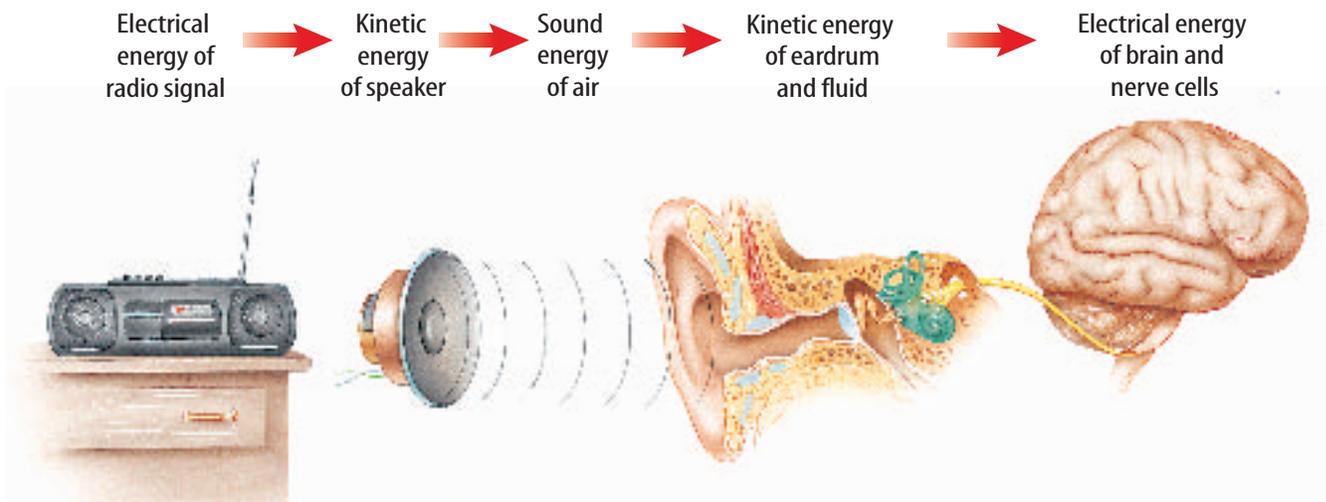
▶ Many skeletal muscles are arranged in pairs that work in opposition to each other. When you bend your arm, the biceps muscle contracts, while the triceps relaxes. When you extend your arm the triceps contracts, and the biceps relaxes.



▶ Skeletal muscles are made up of bundles of muscle cells, or fibers. Each fiber is composed of many bundles of muscle filaments.

▶ A signal from a nerve fiber starts a chemical reaction in the muscle filament. This causes molecules in the muscle filament to gain energy and move. Many filaments moving together cause the muscle to contract.

Figure 12 The simple act of listening to a radio involves many energy transformations. A few are diagrammed here.



Transforming Electrical Energy Every day you use electrical energy. When you flip a light switch, or turn on a radio or television, or use a hair drier, you are transforming electrical energy to other forms of energy. Every time you plug something into a wall outlet, or use a battery, you are using electrical energy. **Figure 12** shows how electrical energy is transformed into other forms of energy when you listen to a radio. A loudspeaker in the radio converts electrical energy into sound waves that travel to your ear—energy in motion. The energy that is carried by the sound waves causes parts of the ear to move also. This energy of motion is transformed again into chemical and electrical energy in nerve cells, which send the energy to your brain. After your brain interprets this energy as a voice or music, where does the energy go? The energy finally is transformed into thermal energy.

Transforming Thermal Energy Different forms of energy can be transformed into thermal energy. For example, chemical energy changes into thermal energy when something burns. Electrical energy changes into thermal energy when a wire that is carrying an electric current gets hot. Thermal energy can be used to heat buildings and keep you warm. Thermal energy also can be used to heat water. If water is heated to its boiling point, it changes to steam. This steam can be used to produce kinetic energy by steam engines, like the steam locomotives that used to pull trains. Thermal energy also can be transformed into radiant energy. For example, when a bar of metal is heated to a high temperature, it glows and gives off light.



Controlling Body Temperature Most organisms have some adaptation for controlling the amount of thermal energy in their bodies. Some living in cooler climates have thick fur coats that help prevent thermal energy from escaping, and some living in desert regions have skin that helps keep thermal energy out. Research some of the adaptations different organisms have for controlling the thermal energy in their bodies.



Figure 13 Thermal energy moves from the hot chocolate to the cooler surroundings.

Explain what happens to the hot chocolate as it loses thermal energy.

Figure 14 A coal-burning power plant transforms the chemical energy in coal into electrical energy.

List some of the other energy sources that power plants use.

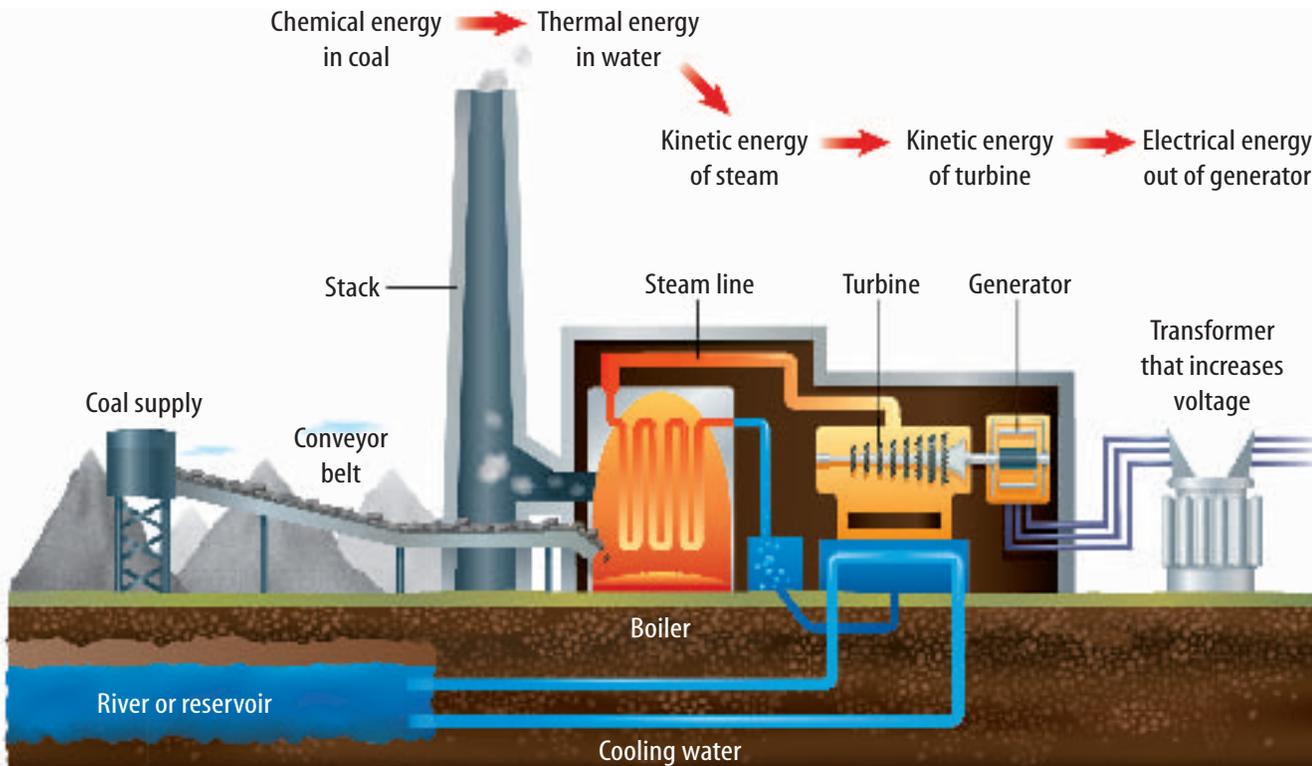
How Thermal Energy Moves Thermal energy can move from one place to another. Look at **Figure 13**. The hot chocolate has thermal energy that moves from the cup to the cooler air around it, and to the cooler spoon. Thermal energy only moves from something at a higher temperature to something at a lower temperature.

Generating Electrical Energy

The enormous amount of electrical energy that is used every day is too large to be stored in batteries. The electrical energy that is available for use at any wall socket must be generated continually by power plants. Every power plant works on the same principle—energy is used to turn a large

generator. A **generator** is a device that transforms kinetic energy into electrical energy. In fossil fuel power plants, coal, oil, or natural gas is burned to boil water. As the hot water boils, the steam rushes through a **turbine**, which contains a set of narrowly spaced fan blades. The steam pushes on the blades and turns the turbine, which in turn rotates a shaft in the generator to produce the electrical energy, as shown in **Figure 14**.

Reading Check What does a generator do?



Power Plants Almost 90 percent of the electrical energy generated in the United States is produced by nuclear and fossil fuel power plants, as shown in **Figure 15**. Other types of power plants include hydroelectric (hi droh ih LEK trihk) and wind. Hydroelectric power plants transform the kinetic energy of moving water into electrical energy. Wind power plants transform the kinetic energy of moving air into electrical energy. In these power plants, a generator converts the kinetic energy of moving water or wind to electrical energy.

To analyze the energy transformations in a power plant, you can diagram the energy changes using arrows. A coal-burning power plant generates electrical energy through the following series of energy transformations.

chemical energy of coal → thermal energy of water → kinetic energy of steam → kinetic energy of turbine → electrical energy out of generator

Nuclear power plants use a similar series of transformations. Hydroelectric plants, however, skip the steps that change water into steam because the water strikes the turbine directly.

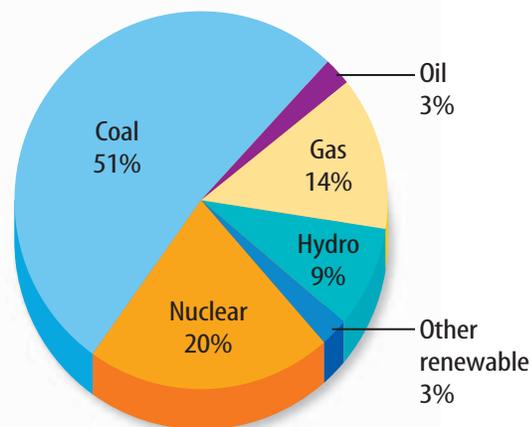


Figure 15 The graph shows sources of electrical energy in the United States.

Name the energy source that you think is being used to provide the electricity for the lights overhead.

section 2 review

Summary

Changing Forms of Energy

- Heat usually is one of the forms of energy produced in energy transformations.
- The law of conservation of energy states that energy cannot be created or destroyed; it can only change form.
- The total energy doesn't change when an energy transformation occurs.
- As an object rises and falls, kinetic and potential energy are transformed into each other, but the total energy doesn't change.

Generating Electrical Energy

- A generator converts kinetic energy into electrical energy.
- Burning fossil fuels produces thermal energy that is used to boil water and produce steam.
- In a power plant, steam is used to spin a turbine which then spins an electric generator.

Self Check

1. **Describe** the conversions between potential and kinetic energy that occur when you shoot a basketball at a basket.
2. **Explain** whether your body gains or loses thermal energy if your body temperature is 37°C and the temperature around you is 25°C.
3. **Describe** a process that converts chemical energy to thermal energy.
4. **Think Critically** A lightbulb converts 10 percent of the electrical energy it uses into radiant energy. Make a hypothesis about the other form of energy produced.

Applying Math

5. **Use a Ratio** How many times greater is the amount of electrical energy produced in the United States by coal-burning power plants than the amount produced by nuclear power plants?

Hearing with Your Jaw

You probably have listened to music using speakers or headphones. Have you ever considered how energy is transferred to get the energy from the radio or CD player to your brain? What type of energy is needed to power the radio or CD player? Where does this energy come from? How does that energy become sound? How does the sound get to you? In this activity, the sound from a radio or CD player is going to travel through a motor before entering your body through your jaw instead of your ears.

Real-World Question

How can energy be transferred from a radio or CD player to your brain?

Goals

- **Identify** energy transfers and transformations.
- **Explain** your observations using the law of conservation of energy.

Materials

radio or CD player
small electrical motor
headphone jack

Procedure

1. Go to one of the places in the room with a motor/radio assembly.
2. Turn on the radio or CD player so that you hear the music.
3. Push the headphone jack into the headphone plug on the radio or CD player.
4. Press the axle of the motor against the side of your jaw.



Conclude and Apply

1. **Describe** what you heard in your Science Journal.
2. **Identify** the form of energy produced by the radio or CD player.
3. **Draw** a diagram to show all of the energy transformations taking place.
4. **Evaluate** Did anything get hotter as a result of this activity? Explain.
5. **Explain** your observations using the law of conservation of energy.

Communicating Your Data

Compare your conclusions with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

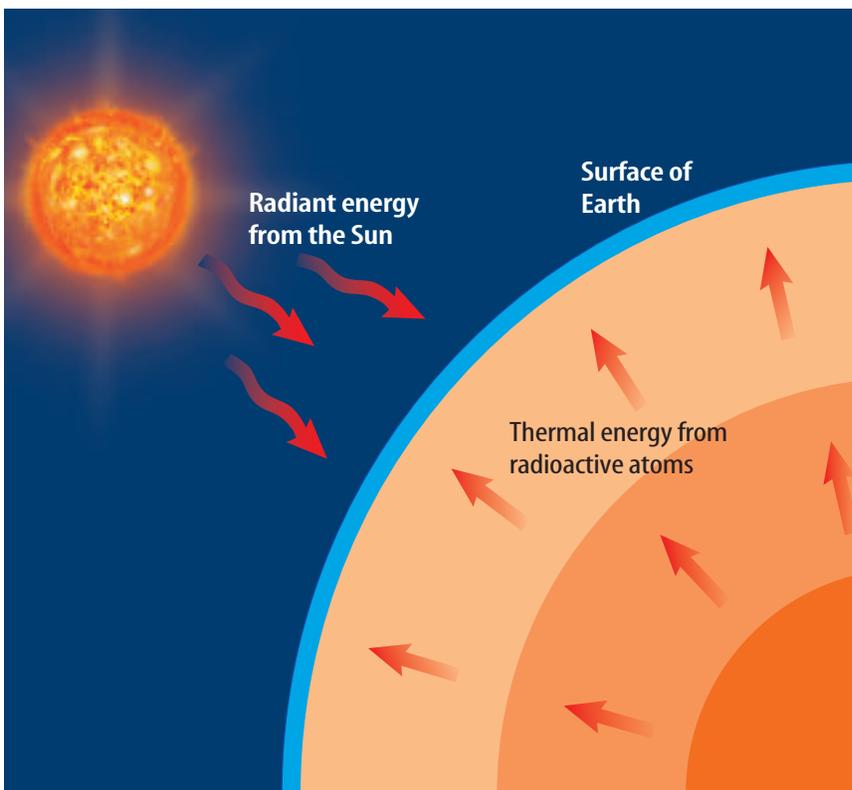
Sources of Energy

Using Energy

Every day, energy is used to provide light and to heat and cool homes, schools, and workplaces. According to the law of conservation of energy, energy can't be created or destroyed. Energy only can change form. If a car or refrigerator can't create the energy they use, then where does this energy come from?

Energy Resources

Energy cannot be made, but must come from the natural world. As you can see in **Figure 16**, the surface of Earth receives energy from two sources—the Sun and radioactive atoms in Earth's interior. The amount of energy Earth receives from the Sun is far greater than the amount generated in Earth's interior. Nearly all the energy you used today can be traced to the Sun, even the gasoline used to power the car or school bus you came to school in.



as you read

What You'll Learn

- **Explain** what renewable, non-renewable, and alternative resources are.
- **Describe** the advantages and disadvantages of using various energy sources.

Why It's Important

Energy is vital for survival and making life comfortable. Developing new energy sources will improve modern standards of living.

Review Vocabulary

resource: a natural feature or phenomenon that enhances the quality of life

New Vocabulary

- nonrenewable resource
- renewable resource
- alternative resource
- inexhaustible resource
- photovoltaic

Figure 16 All the energy you use can be traced to one of two sources—the Sun or radioactive atoms in Earth's interior.

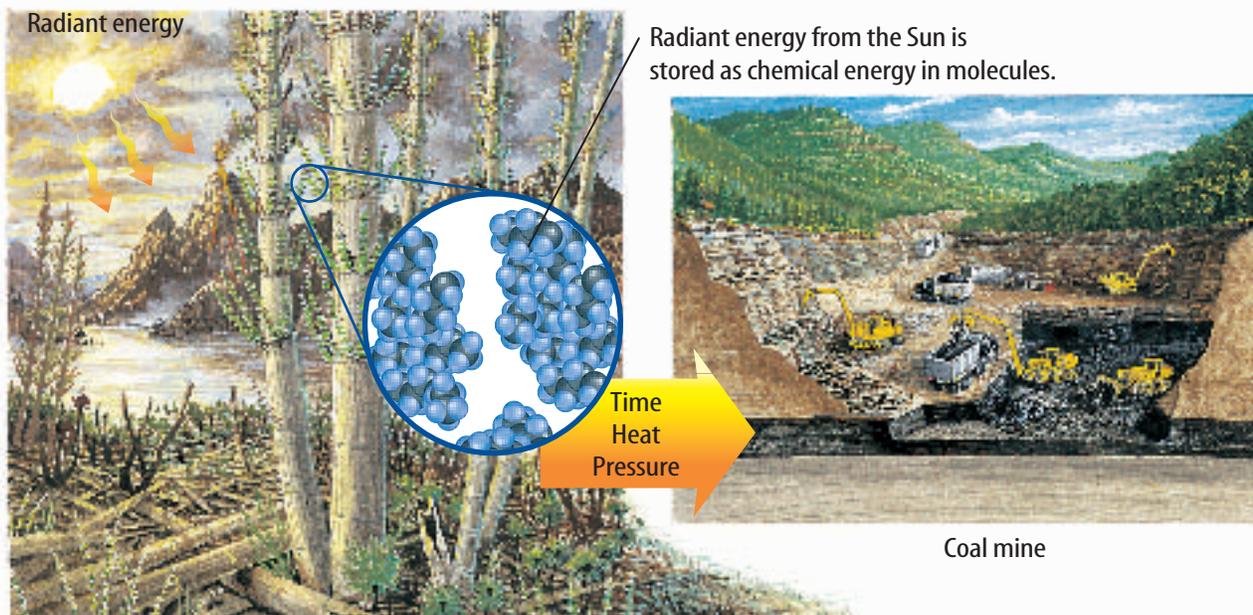


Figure 17 Coal is formed after the molecules in ancient plants are heated under pressure for millions of years. The energy stored by the molecules in coal originally came from the Sun.

Fossil Fuels

Fossil fuels are coal, oil, and natural gas. Oil and natural gas were made from the remains of microscopic organisms that lived in Earth's oceans millions of years ago. Heat and pressure gradually turned these ancient organisms into oil and natural gas. Coal was formed by a similar process from the remains of ancient plants that once lived on land, as shown in **Figure 17**.

Through the process of photosynthesis, ancient plants converted the radiant energy in sunlight to chemical energy stored in various types of molecules. Heat and pressure changed these molecules into other types of molecules as fossil fuels formed. Chemical energy stored in these molecules is released when fossil fuels are burned.

Using Fossil Fuels The energy used when you ride in a car, turn on a light, or use an electric appliance usually comes from burning fossil fuels. However, it takes millions of years to replace each drop of gasoline and each lump of coal that is burned. This means that the supply of oil on Earth will continue to decrease as oil is used. An energy source that is used up much faster than it can be replaced is a **nonrenewable resource**. Fossil fuels are nonrenewable resources.

Burning fossil fuels to produce energy also generates chemical compounds that cause pollution. Each year billions of kilograms of air pollutants are produced by burning fossil fuels. These pollutants can cause respiratory illnesses and acid rain. Also, the carbon dioxide gas formed when fossil fuels are burned might cause Earth's climate to warm.



Energy Source Origins

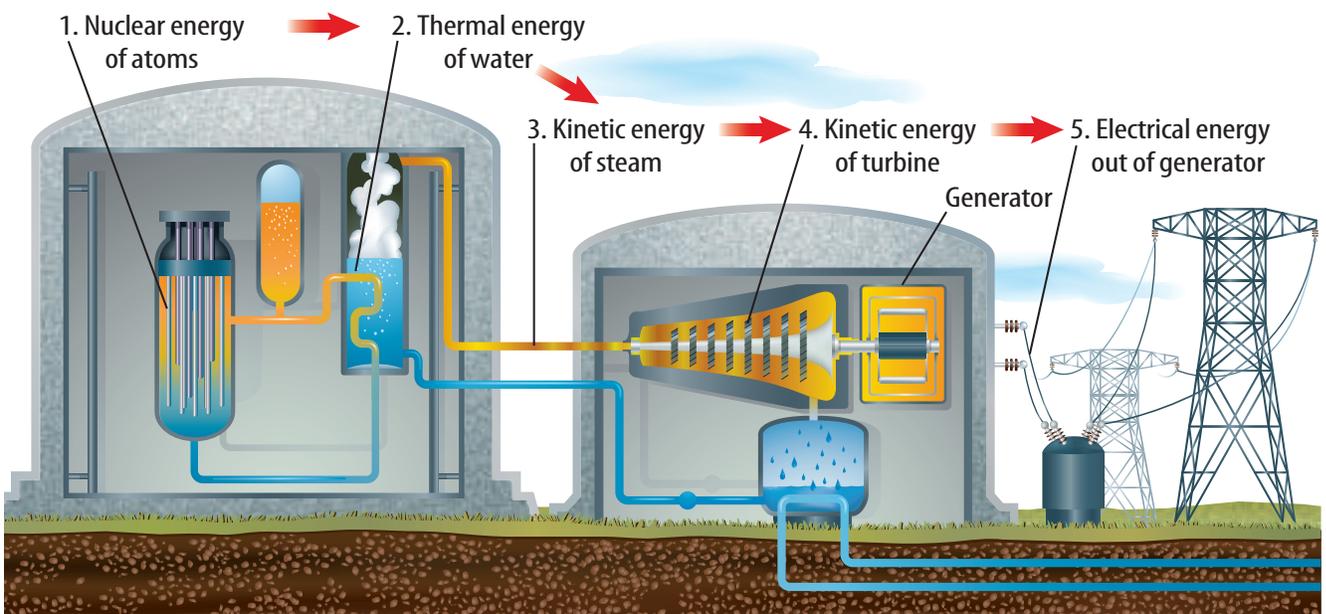
The kinds of fossil fuels found in the ground depend on the kinds of organisms (animal or plant) that died and were buried in that spot. Research coal, oil, and natural gas to find out what types of organisms were primarily responsible for producing each.

Nuclear Energy

Can you imagine running an automobile on 1 kg of fuel that releases almost 3 million times more energy than 1 L of gas? What could supply so much energy from so little mass? The answer is the nuclei of uranium atoms. Some of these nuclei are unstable and break apart, releasing enormous amounts of energy in the process. This energy can be used to generate electricity by heating water to produce steam that spins an electric generator, as shown in **Figure 18**. Because no fossil fuels are burned, generating electricity using nuclear energy helps make the supply of fossil fuels last longer. Also, unlike fossil fuel power plants, nuclear power plants produce almost no air pollution. In one year, a typical nuclear power plant generates enough energy to supply 600,000 homes with power and produces only 1 m³ of waste.

Nuclear Wastes Like all energy sources, nuclear energy has its advantages and disadvantages. One disadvantage is the amount of uranium in Earth's crust is nonrenewable. Another is that the waste produced by nuclear power plants is radioactive and can be dangerous to living things. Some of the materials in the nuclear waste will remain radioactive for many thousands of years. As a result the waste must be stored so no radioactivity is released into the environment for a long time. One method is to seal the waste in a ceramic material, place the ceramic in protective containers, and then bury the containers far underground. However, the burial site would have to be chosen carefully so underground water supplies aren't contaminated. Also, the site would have to be safe from earthquakes and other natural disasters that might cause radioactive material to be released.

Figure 18 To obtain electrical energy from nuclear energy, a series of energy transformations must occur.



Hydroelectricity

Currently, transforming the potential energy of water that is trapped behind dams supplies the world with almost 20 percent of its electrical energy. Hydroelectricity is the largest renewable source of energy. A **renewable resource** is an energy source that is replenished continually. As long as enough rain and snow fall to keep rivers flowing, hydroelectric power plants can generate electrical energy, as shown in **Figure 19**.

Although production of hydroelectricity is largely pollution free, it has one major problem. It disrupts the life cycle of aquatic animals, especially fish. This is particularly true in the Northwest where salmon spawn and run. Because salmon return to the spot where they were hatched to lay their eggs, the development of dams has hindered a large fraction of salmon from reproducing. This has greatly reduced the salmon population. Efforts to correct the problem have resulted in plans to remove a number of dams. In an attempt to help fish bypass some dams, fish ladders are being installed. Like most energy sources, hydroelectricity has advantages and disadvantages.



Topic: Hydroelectricity

Visit bookm.msscience.com for Web links to information about the use of hydroelectricity in various parts of the world.

Activity On a map of the world, show where the use of hydroelectricity is the greatest.

Applying Science

Is energy consumption outpacing production?

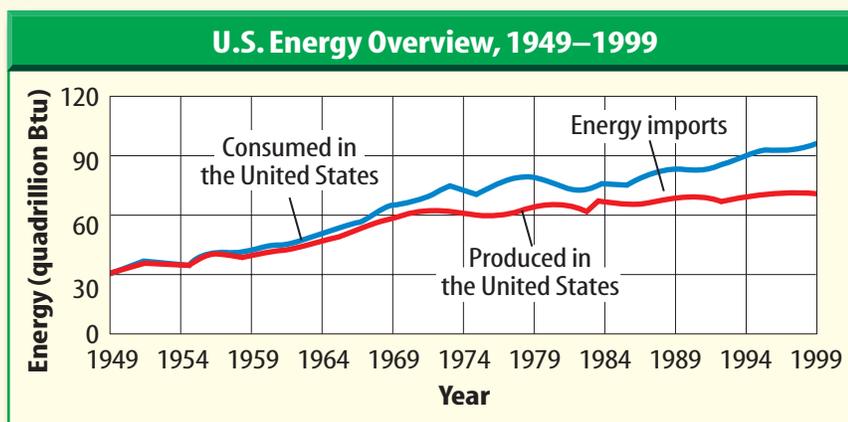
You use energy every day—to get to school, to watch TV, and to heat or cool your home. The amount of energy consumed by an average person has increased over time. Consequently, more energy must be produced.

Identifying the Problem

The graph above shows the energy produced and consumed in the United States from 1949 to 1999. How does energy that is consumed by Americans compare with energy that is produced in the United States?

Solving the Problem

1. Determine the approximate amount of energy produced in 1949 and in 1999 and how much it has increased in 50 years. Has it doubled or tripled?
2. Do the same for consumption. Has it doubled or tripled?
3. Using your answers for steps 1 and 2 and the graph, where does the additional energy that is needed come from? Give some examples.



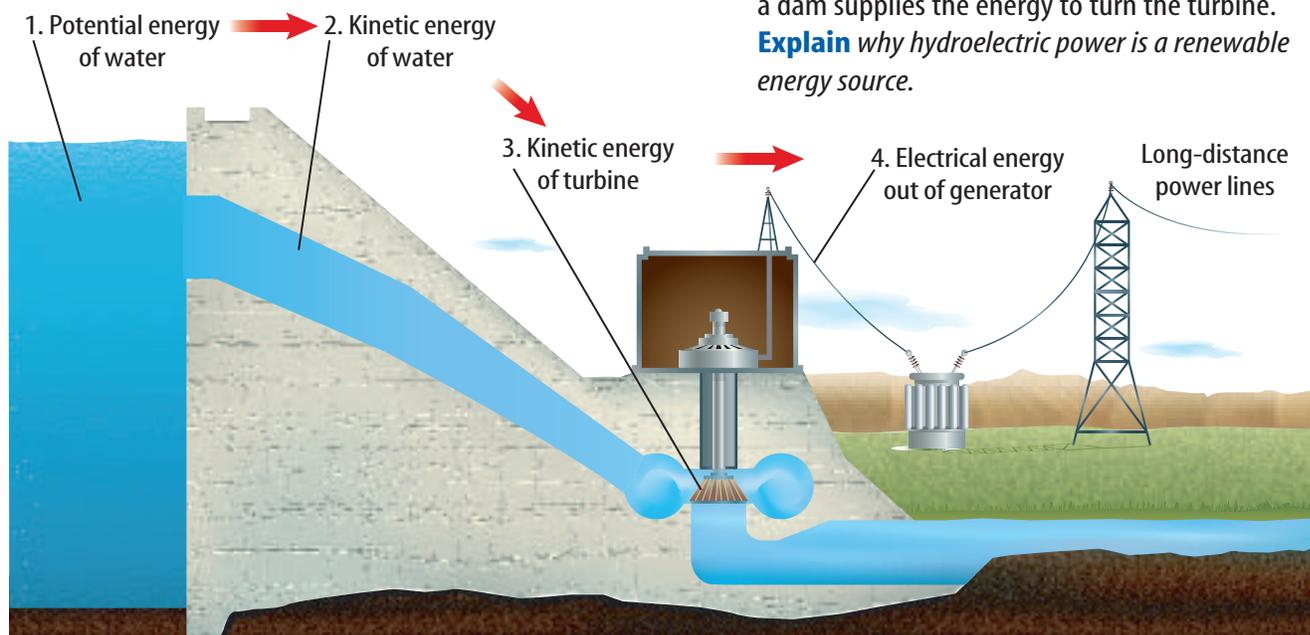


Figure 19 The potential energy of water behind a dam supplies the energy to turn the turbine. **Explain** why hydroelectric power is a renewable energy source.

Alternative Sources of Energy

Electrical energy can be generated in several ways. However, each has disadvantages that can affect the environment and the quality of life for humans. Research is being done to develop new sources of energy that are safer and cause less harm to the environment. These sources often are called **alternative resources**. These alternative resources include solar energy, wind, and geothermal energy.

Solar Energy

The Sun is the origin of almost all the energy that is used on Earth. Because the Sun will go on producing an enormous amount of energy for billions of years, the Sun is an inexhaustible source of energy. An **inexhaustible resource** is an energy source that can't be used up by humans.

Each day, on average, the amount of solar energy that strikes the United States is more than the total amount of energy used by the entire country in a year. However, less than 0.1 percent of the energy used in the United States comes directly from the Sun. One reason is that solar energy is more expensive to use than fossil fuels. However, as the supply of fossil fuels decreases, the cost of finding and mining these fuels might increase. Then, it may be cheaper to use solar energy or other energy sources to generate electricity and heat buildings than to use fossil fuels.

Reading Check What is an inexhaustible energy source?

Mini LAB

Building a Solar Collector

Procedure

1. Line a **large pot** with **black plastic** and fill with water.
2. Stretch **clear-plastic wrap** over the pot and tape it taut.
3. Make a slit in the top and slide a **thermometer** or a **computer probe** into the water.
4. Place your solar collector in direct sunlight and monitor the temperature change every 3 min for 15 min.
5. Repeat your experiment without using any black plastic.

Analysis

1. Graph the temperature changes in both setups.
2. Explain how your solar collector works.

Figure 20 Solar energy can be collected and utilized by individuals using thermal collectors or photovoltaic collectors.



Collecting the Sun's Energy Two types of collectors capture the Sun's rays. If you look around your neighborhood, you might see large, rectangular panels attached to the roofs of buildings or houses. If, as in **Figure 20**, pipes come out of the panel, it is a thermal collector. Using a black surface, a thermal collector heats water by directly absorbing the Sun's radiant energy. Water circulating in this system can be heated to about 70°C. The hot water can be pumped through the house to provide heat. Also, the hot water can be used for washing and bathing. If the panel has no pipes, it is a photovoltaic (foh toh vol TAY ihk) collector, like the one pictured in **Figure 20**. A **photovoltaic** is a device that transforms radiant energy directly into electrical energy. Photovoltaics are used to power calculators and satellites, including the *International Space Station*.

 **Reading Check** What does a photovoltaic do?

Geothermal Energy

Imagine you could take a journey to the center of Earth—down to about 6,400 km below the surface. As you went deeper and deeper, you would find the temperature increasing. In fact, after going only about 3 km, the temperature could have increased enough to boil water. At a depth of 100 km, the temperature could be over 900°C. The heat generated inside Earth is called geothermal energy. Some of this heat is produced when unstable radioactive atoms inside Earth decay, converting nuclear energy to thermal energy.

At some places deep within Earth the temperature is hot enough to melt rock. This molten rock, or magma, can rise up close to the surface through cracks in the crust. During a volcanic eruption, magma reaches the surface. In other places, magma gets close to the surface and heats the rock around it.

Geothermal Reservoirs In some regions where magma is close to the surface, rainwater and water from melted snow can seep down to the hot rock through cracks and other openings in Earth's surface. The water then becomes hot and sometimes can form steam. The hot water and steam can be trapped under high pressure in cracks and pockets called geothermal reservoirs. In some places, the hot water and steam are close enough to the surface to form hot springs and geysers.

Geothermal Power Plants In places where the geothermal reservoirs are less than several kilometers deep, wells can be drilled to reach them. The hot water and steam produced by geothermal energy then can be used by geothermal power plants, like the one in **Figure 21**, to generate electricity.

Most geothermal reservoirs contain hot water under high pressure. **Figure 22** shows how these reservoirs can be used to generate electricity. While geothermal power is an inexhaustible source of energy, geothermal power plants can be built only in regions where geothermal reservoirs are close to the surface, such as in the western United States.

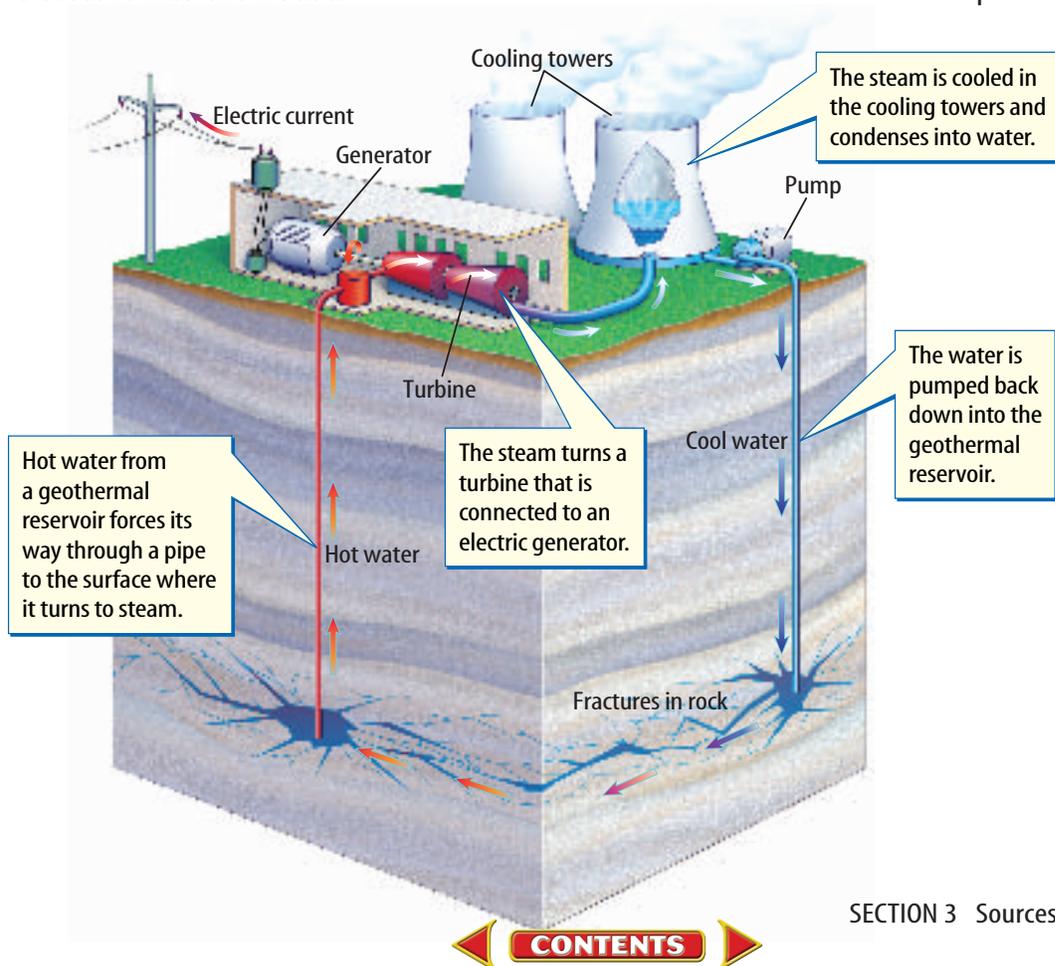
Heat Pumps Geothermal heat helps keep the temperature of the ground at a depth of several meters at a nearly constant temperature of about 10° to 20°C. This constant temperature can be used to cool and heat buildings by using a heat pump.

A heat pump contains a water-filled loop of pipe that is buried to a depth where the temperature is nearly constant. In summer the air is warmer than this underground temperature. Warm water from the building is pumped through the pipe down into the ground. The water cools and then is pumped back to the house where it absorbs more heat, and the cycle is repeated. During the winter, the air is cooler than the ground below. Then, cool water absorbs heat from the ground and releases it into the house.



Figure 21 This geothermal power plant in Nevada produces enough electricity to power about 50,000 homes.

Figure 22 The hot water in a geothermal reservoir is used to generate electricity in a geothermal power plant.



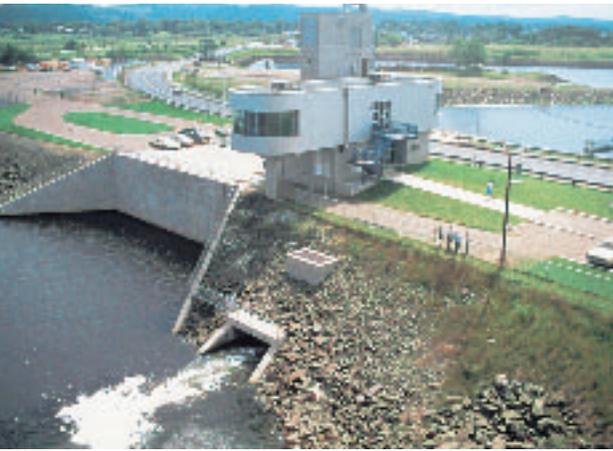


Figure 23 This tidal power plant in Annapolis Royal, Nova Scotia, is the only operating tidal power plant in North America.

Energy from the Oceans

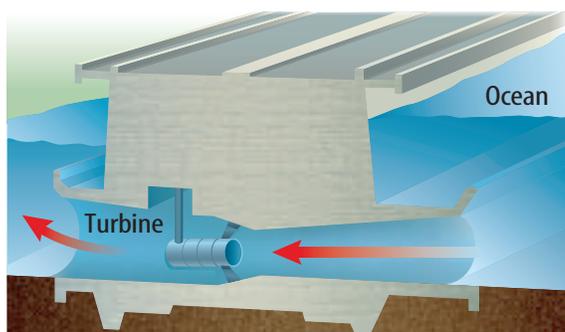
The ocean is in constant motion. If you've been to the seashore you've seen waves roll in. You may have seen the level of the ocean rise and fall over a period of about a half day. This rise and fall in the ocean level is called a tide. The constant movement of the ocean is an inexhaustible source of mechanical energy that can be converted into electric energy. While methods are still being developed to convert the motion in ocean waves to electric energy, several electric power plants using tidal motion have been built.

Using Tidal Energy A high tide and a low tide each occur about twice a day. In most places the level of the ocean changes by less than a few meters. However, in some places the change is much greater. In the Bay of Fundy in Eastern Canada, the ocean level changes by 16 m between high tide and low tide. Almost 14 trillion kg of water move into or out of the bay between high and low tide.

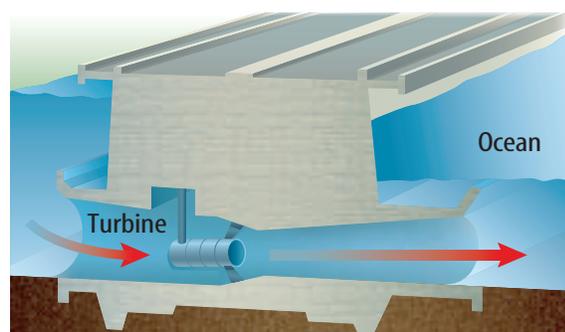
Figure 23 shows an electric power plant that has been built along the Bay of Fundy. This power plant generates enough electric energy to power about 12,000 homes. The power plant is constructed so that as the tide rises, water flows through a turbine that causes an electric generator to spin, as shown in **Figure 24A**. The water is then trapped behind a dam. When the tide goes out, the trapped water behind the dam is released through the turbine to generate more electricity, as shown in **Figure 24B**. Each day electric power is generated for about ten hours when the tide is rising and falling.

Figure 24 A tidal power plant can generate electricity when the tide is coming in and going out.

While tidal energy is a nonpolluting, inexhaustible energy source, its use is limited. Only in a few places is the difference between high and low tide large enough to enable a large electric power plant to be built.



A As the tide comes in, it turns a turbine connected to a generator. When high tide occurs, gates are closed that trap water behind a dam.



B As the tide goes out and the ocean level drops, the gates are opened and water from behind the dam flows through the turbine, causing it to spin and turn a generator.

Wind

Wind is another inexhaustible supply of energy. Modern windmills, like the ones in **Figure 25**, convert the kinetic energy of the wind to electrical energy. The propeller is connected to a generator so that electrical energy is generated when wind spins the propeller. These windmills produce almost no pollution. Some disadvantages are that windmills produce noise and that large areas of land are needed. Also, studies have shown that birds sometimes are killed by windmills.

Conserving Energy

Fossil fuels are a valuable resource. Not only are they burned to provide energy, but oil and coal also are used to make plastics and other materials. One way to make the supply of fossil fuels last longer is to use less energy. Reducing the use of energy is called conserving energy.

You can conserve energy and also save money by turning off lights and appliances such as televisions when you are not using them. Also keep doors and windows closed tightly when it's cold or hot to keep heat from leaking out of or into your house. Energy could also be conserved if buildings are properly insulated, especially around windows. The use of oil could be reduced if cars were used less and made more efficient, so they went farther on a liter of gas. Recycling materials such as aluminum cans and glass also helps conserve energy.



Figure 25 Windmills work on the same basic principles as a power plant. Instead of steam turning a turbine, wind turns the rotors. **Describe** some of the advantages and disadvantages of using windmills.

section 3 review

Summary

Nonrenewable Resources

- All energy resources have advantages and disadvantages.
- Nonrenewable energy resources are used faster than they are replaced.
- Fossil fuels include oil, coal, and natural gas and are nonrenewable resources. Nuclear energy is a nonrenewable resource.

Renewable and Alternative Resources

- Renewable energy resources, such as hydroelectricity, are resources that are replenished continually.
- Alternative energy sources include solar energy, wind energy, and geothermal energy.

Self Check

1. **Diagram** the energy conversions that occur when coal is formed, and then burned to produce thermal energy.
2. **Explain** why solar energy is considered an inexhaustible source of energy.
3. **Explain** how a heat pump is used to both heat and cool a building.
4. **Think Critically** Identify advantages and disadvantages of using fossil fuels, hydroelectricity, and solar energy as energy sources.

Applying Math

5. **Use a Ratio** Earth's temperature increases with depth. Suppose the temperature increase inside Earth is 500°C at a depth of 50 km. What is the temperature increase at a depth of 10 km?

Energy to POWER YOUR Life

Goals

- **Identify** how energy you use is produced and delivered.
- **Investigate** alternative sources for the energy you use.
- **Outline** a plan for how these alternative sources of energy could be used.

Data Source



Visit bookm.msscience.com/internet_lab for more information about sources of energy and for data collected by other students.

Real-World Question

Over the past 100 years, the amount of energy used in the United States and elsewhere has greatly increased. Today, a number of energy sources are available, such as coal, oil, natural gas, nuclear energy, hydroelectric power, wind, and solar energy. Some of these energy sources are being used up and are nonrenewable, but others are replaced as fast as they are used and, therefore, are renewable. Some energy sources are so vast that human usage has almost no effect on the amount available. These energy sources are inexhaustible.

Think about the types of energy you use at home and school every day. In this lab, you will investigate how and where energy is produced, and how it gets to you. You will also investigate alternative ways energy can be produced, and whether these sources are renewable, nonrenewable, or inexhaustible. What are the sources of the energy you use every day?



Local Energy Information

Energy Type	
Where is that energy produced?	
How is that energy produced?	Do not write in this book.
How is that energy delivered to you?	
Is the energy source renewable, nonrenewable, or inexhaustible?	
What type of alternative energy source could you use instead?	

Using Scientific Methods

▶ **Make a Plan**

1. Think about the activities you do every day and the things you use. When you watch television, listen to the radio, ride in a car, use a hair drier, or turn on the air conditioning, you use energy. Select one activity or appliance that uses energy.
2. **Identify** the type of energy that is used.
3. **Investigate** how that energy is produced and delivered to you.
4. **Determine** if the energy source is renewable, nonrenewable, or inexhaustible.
5. If your energy source is nonrenewable, describe how the energy you use could be produced by renewable sources.

▶ **Follow Your Plan**

1. Make sure your teacher approves your plan before you start.
2. Organize your findings in a data table, similar to the one that is shown.

▶ **Analyze Your Data**

1. **Describe** the process for producing and delivering the energy source you researched. How is it created, and how does it get to you?
2. How much energy is produced by the energy source you investigated?
3. Is the energy source you researched renewable, nonrenewable, or inexhaustible? Why?

▶ **Conclude and Apply**

1. **Describe** If the energy source you investigated is nonrenewable, how can the use of this energy source be reduced?
2. **Organize** What alternative sources of energy could you use for everyday energy needs? On the computer, create a plan for using renewable or inexhaustible sources.



Communicating **Your Data**

Find this lab using the link below. Post your data in the table that is provided. **Compare** your data to those of other students. **Combine** your data with those of other students and make inferences using the combined data.

Science  online

bookm.msscience.com/internet_lab

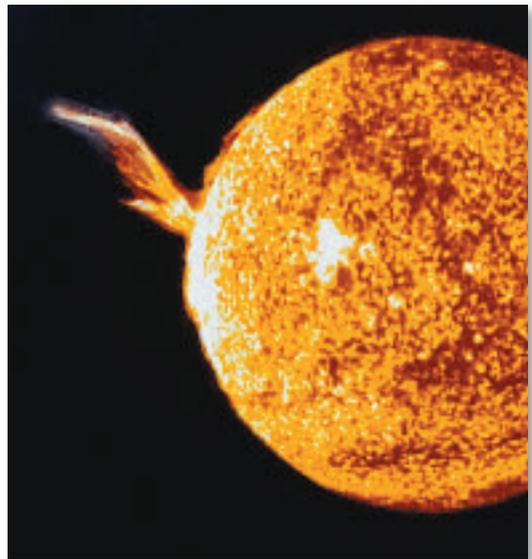
Energy to Burn



Did you know...

... **The energy released by the average hurricane** is equal to about 200 times the total energy produced by all of the world's power plants. Almost all of this energy is released as heat when raindrops form.

... **The energy Earth gets each half hour from the Sun** is enough to meet the world's demands for a year. Renewable and inexhaustible resources, including the Sun, account for only 18 percent of the energy that is used worldwide.



... **The Calories in one medium apple** will give you enough energy to walk for about 15 min, swim for about 10 min, or jog for about 9 min.

Applying Math If walking for 15 min requires 80 Calories of fuel (from food), how many Calories would someone need to consume to walk for 1 h?

Write About It

Where would you place solar collectors in the United States? Why? For more information on solar energy, go to bookm.msscience.com/science_stats.



Reviewing Main Ideas

Section 1 What is energy?

1. Energy is the ability to cause change.
2. A moving object has kinetic energy that depends on the object's mass and speed.
3. Potential energy is energy due to position and depends on an object's mass and height.
4. Light carries radiant energy, electric current carries electrical energy, and atomic nuclei contain nuclear energy.

Section 2 Energy Transformations

1. Energy can be transformed from one form to another. Thermal energy is usually produced when energy transformations occur.
2. The law of conservation of energy states that energy cannot be created or destroyed.

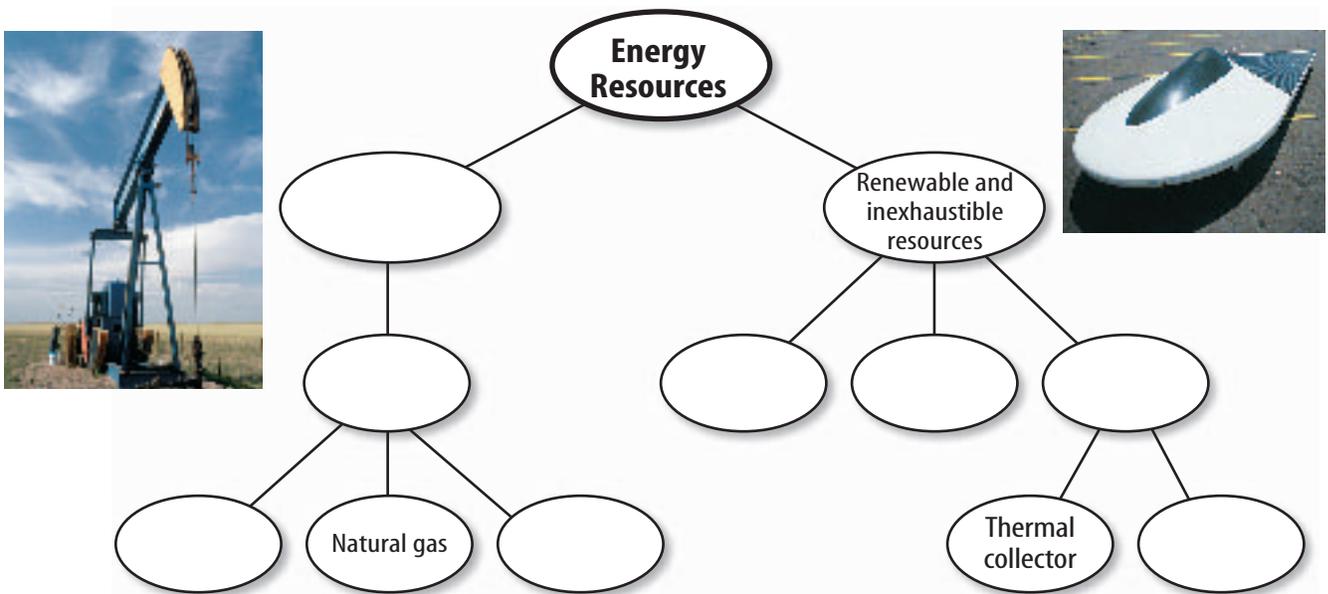
3. Electric power plants convert a source of energy into electrical energy. Steam spins a turbine which spins an electric generator.

Section 3 Sources of Energy

1. The use of an energy source has advantages and disadvantages.
2. Fossil fuels and nuclear energy are nonrenewable energy sources that are consumed faster than they can be replaced.
3. Hydroelectricity is a renewable energy source that is continually being replaced.
4. Alternative energy sources include solar, wind, and geothermal energy. Solar energy is an inexhaustible energy source.

Visualizing Main Ideas

Copy and complete the concept map using the following terms: fossil fuels, hydroelectric, solar, wind, oil, coal, photovoltaic, and nonrenewable resources.



Using Vocabulary

alternative resource p. 143	nonrenewable resource p. 140
chemical energy p. 129	nuclear energy p. 130
electrical energy p. 130	photovoltaic p. 144
energy p. 126	potential energy p. 128
generator p. 136	radiant energy p. 129
inexhaustible resource p. 143	renewable resource p. 142
kinetic energy p. 127	thermal energy p. 128
law of conservation of energy p. 132	turbine p. 136

For each of the terms below, explain the relationship that exists.

- electrical energy—nuclear energy
- turbine—generator
- photovoltaic—radiant energy—electrical energy
- renewable resource— inexhaustible resource
- potential energy—kinetic energy
- kinetic energy—electrical energy—generator
- thermal energy—radiant energy
- law of conservation of energy—energy transformations
- nonrenewable resource—chemical energy

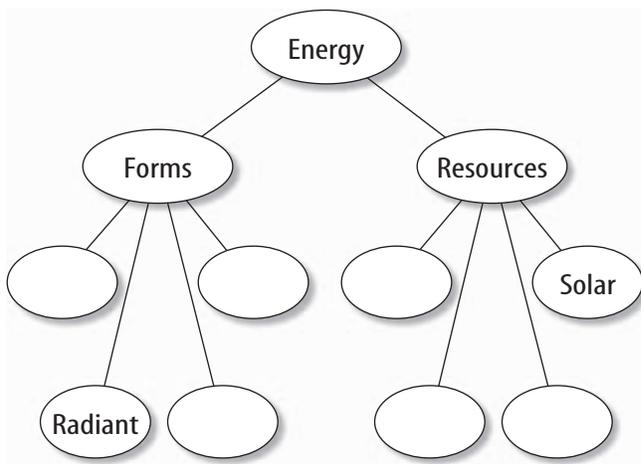
Checking Concepts

Choose the word or phrase that best answers the question.

- Objects that are able to fall have what type of energy?
 - kinetic
 - radiant
 - potential
 - electrical
- Which form of energy does light have?
 - electrical
 - nuclear
 - kinetic
 - radiant
- Muscles perform what type of energy transformation?
 - kinetic to potential
 - kinetic to electrical
 - thermal to radiant
 - chemical to kinetic
- Photovoltaics perform what type of energy transformation?
 - thermal to radiant
 - kinetic to electrical
 - radiant to electrical
 - electrical to thermal
- The form of energy that food contains is which of the following?
 - chemical
 - potential
 - radiant
 - electrical
- Solar energy, wind, and geothermal are what type of energy resource?
 - inexhaustible
 - inexpensive
 - nonrenewable
 - chemical
- Which of the following is a nonrenewable source of energy?
 - hydroelectricity
 - nuclear
 - wind
 - solar
- A generator is NOT required to generate electrical energy when which of the following energy sources is used?
 - solar
 - wind
 - hydroelectric
 - nuclear
- Which of the following are fossil fuels?
 - gas
 - coal
 - oil
 - all of these
- Almost all of the energy that is used on Earth's surface comes from which of the following energy sources?
 - radioactivity
 - the Sun
 - chemicals
 - wind

Thinking Critically

20. **Explain** how the motion of a swing illustrates the transformation between potential and kinetic energy.
21. **Explain** what happens to the kinetic energy of a skateboard that is coasting along a flat surface, slows down, and comes to a stop.
22. **Describe** the energy transformations that occur in the process of toasting a bagel in an electric toaster.
23. **Compare and contrast** the formation of coal and the formation of oil and natural gas.
24. **Explain** the difference between the law of conservation of energy and conserving energy. How can conserving energy help prevent energy shortages?
25. **Make a Hypothesis** about how spacecraft that travel through the solar system obtain the energy they need to operate. Do research to verify your hypothesis.
26. **Concept Map** Copy and complete this concept map about energy.



27. **Diagram** the energy transformations that occur when you rub sandpaper on a piece of wood and the wood becomes warm.

Performance Activities

28. **Multimedia Presentation** Alternative sources of energy that weren't discussed include biomass energy, wave energy, and hydrogen fuel cells. Research an alternative energy source and then prepare a digital slide show about the information you found. Use the concepts you learned from this chapter to inform your classmates about the future prospects of using such an energy source on a large scale.

Applying Math

29. **Calculate Number of Power Plants** A certain type of power plant is designed to provide energy for 10,000 homes. How many of these power plants would be needed to provide energy for 300,000 homes?

Use the table below to answer questions 30 and 31.

Energy Sources Used in the United States	
Energy Source	Percent of Energy Used
Coal	23%
Oil	39%
Natural gas	23%
Nuclear	8%
Hydroelectric	4%
Other	3%

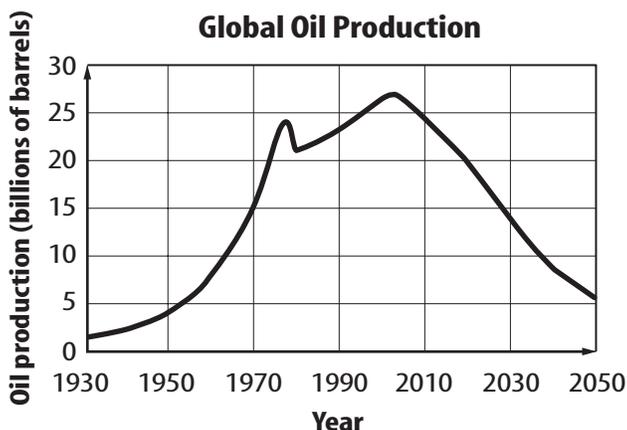
30. **Use Percentages** According to the data in the table above, what percentage of the energy used in the United States comes from fossil fuels?
31. **Calculate a Ratio** How many times greater is the amount of energy that comes from fossil fuels than the amount of energy from all other energy sources?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

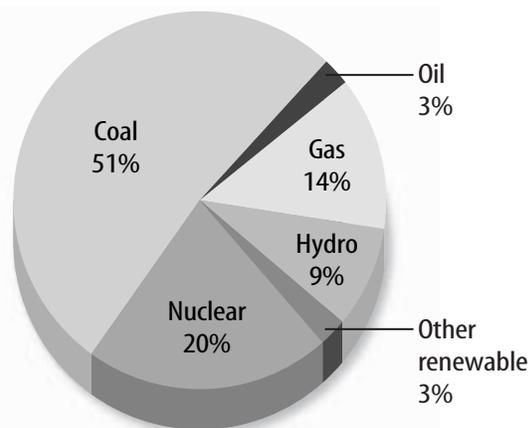
- The kinetic energy of a moving object increases if which of the following occurs?
 - Its mass decreases.
 - Its speed increases.
 - Its height above the ground increases.
 - Its temperature increases.

Use the graph below to answer questions 2–4.



- According to the graph above, in which year will global oil production be at a maximum?
 - 1974
 - 2002
 - 2010
 - 2050
- Approximately how many times greater was oil production in 1970 than oil production in 1950?
 - 2 times
 - 10 times
 - 6 times
 - 3 times
- In which year will the production of oil be equal to the oil production in 1970?
 - 2010
 - 2015
 - 2022
 - 2028
- Which of the following energy sources is being used faster than it can be replaced?
 - tidal
 - wind
 - fossil fuels
 - hydroelectric

Use the circle graph below to answer question 6.



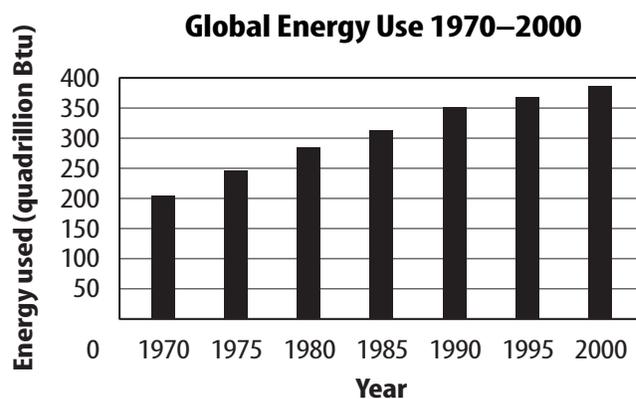
- The circle graph shows the sources of electrical energy in the United States. In 2002, the total amount of electrical energy produced in the United States was 38.2 quads. How much electrical energy was produced by nuclear power plants?
 - 3.0 quads
 - 3.8 quads
 - 7.6 quads
 - 35.1 quads
- When chemical energy is converted into thermal energy, which of the following must be true?
 - The total amount of thermal energy plus chemical energy changes.
 - Only the amount of chemical energy changes.
 - Only the amount of thermal energy changes.
 - The total amount of thermal energy plus chemical energy doesn't change.
- A softball player hits a fly ball. Which of the following describes the energy conversion that occurs as it falls from its highest point?
 - kinetic to potential
 - potential to kinetic
 - thermal to potential
 - thermal to kinetic

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

- Why is it impossible to build a machine that produces more energy than it uses?
- You toss a ball upward and then catch it on the way down. The height of the ball above the ground when it leaves your hand on the way up and when you catch it is the same. Compare the ball's kinetic energy when it leaves your hand and just before you catch it.
- A basket ball is dropped from a height of 2 m and another identical basketball is dropped from a height of 4 m. Which ball has more kinetic energy just before it hits the ground?

Use the graph below to answer questions 12 and 13.



- According to the graph above, by about how many times did the global use of energy increase from 1970 to 2000?
- Over which five-year time period was the increase in global energy use the largest?

Test-Taking Tip

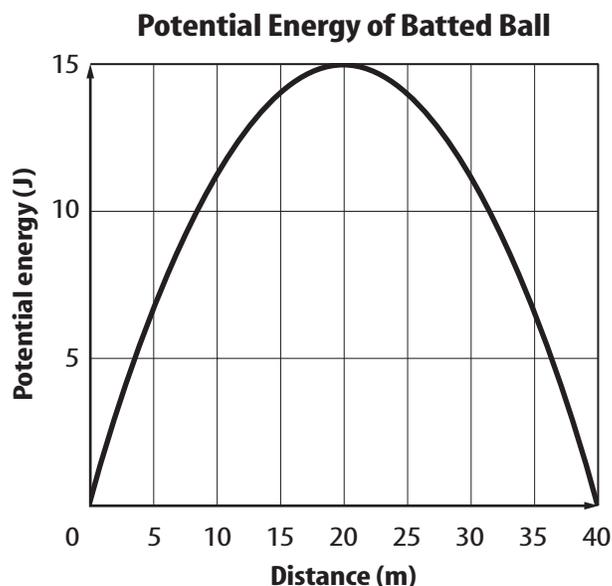
Do Your Studying Regularly Do not “cram” the night before the test. It can hamper your memory and make you tired.

Part 3 Open Ended

Record your answers on a sheet of paper.

- When you drop a tennis ball, it hits the floor and bounces back up. But it does not reach the same height as released, and each successive upward bounce is smaller than the one previous. However, you notice the tennis ball is slightly warmer after it finishes bouncing. Explain how the law of conservation of energy is obeyed.

Use the graph below to answer questions 15–17.



- The graph shows how the potential energy of a batted ball depends on distance from the batter. At what distances is the kinetic energy of the ball the greatest?
- At what distance from the batter is the height of the ball the greatest?
- How much less is the kinetic energy of the ball at a distance of 20 m from the batter than at a distance of 0 m?
- List advantages and disadvantages of the following energy sources: fossil fuels, nuclear energy, and geothermal energy.