section 1

Fossil Fuels

Reading Guide

What You'll Learn

- **Discuss** properties and uses of fossil fuels.
- **Explain** how fossil fuels are formed.
- **Describe** how the chemical energy in fossil fuels is converted into electrical energy.

Why It's Important

Fossil fuels are used to generate most of the energy you use every day.

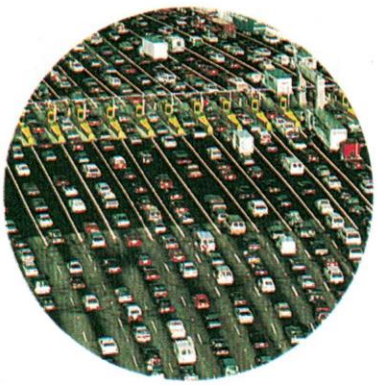
Review Vocabulary

chemical potential energy: the energy stored in the chemical bonds between atoms in molecules

New Vocabulary

- fossil fuel
- petroleum
- nonrenewable resource

Figure 1 Energy is used in many ways.



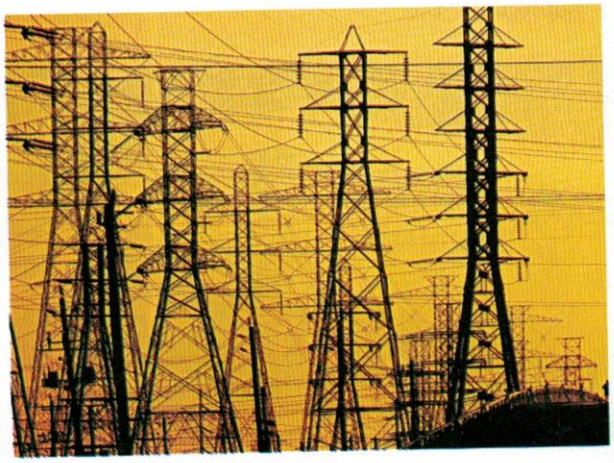
Automobiles burn gasoline to provide energy.

Using Energy

How many different ways have you used energy today? You can see energy being used in many ways, throughout the day, such as those shown in **Figure 1.** Furnaces and stoves use thermal energy to heat buildings and cook food. Air conditioners use electrical energy to move thermal energy outdoors. Cars and other vehicles use mechanical energy to carry people and materials from one part of the country to another.

Transforming Energy According to the law of conservation of energy, energy cannot be created or destroyed. Energy can only be transformed, or converted, from one form to another. To use energy means to transform one form of energy to another form of energy that can perform a useful function. For example, energy is used when the chemical energy in fuels is transformed into thermal energy that is used to heat your home.

Sometimes energy is transformed into a form that isn't useful. For example, when an electric current flows through power lines, about 10 percent of the electrical energy is changed to thermal energy. This reduces the amount of useful electrical energy that is delivered to homes, schools, and businesses.



Power lines like these carry the electrical energy you use every day.

Energy Use in the United States More energy is used in the United States than in any other country in the world. **Figure 2** shows energy usage in the United States. About 20 percent of the energy is used in homes for heating and cooling, to run appliances, and to provide lighting and hot water. About 27 percent is used for transportation powering vehicles such as cars, trucks, and aircraft. Another 16 percent is used by businesses to heat, cool, and light stores, shops, and office buildings. Finally, about 37 percent of this energy is used by industry and agriculture to manufacture products and produce food. **Figure 2** also shows the main sources of the energy used in the United States. Almost 85 percent of the energy used in the United States comes from burning petroleum, natural gas, and coal. Nuclear power plants provide about eight percent of the energy used in the United States.

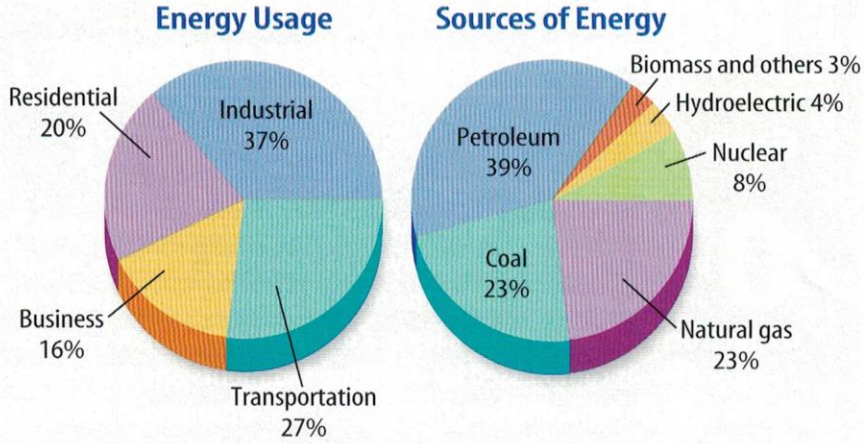


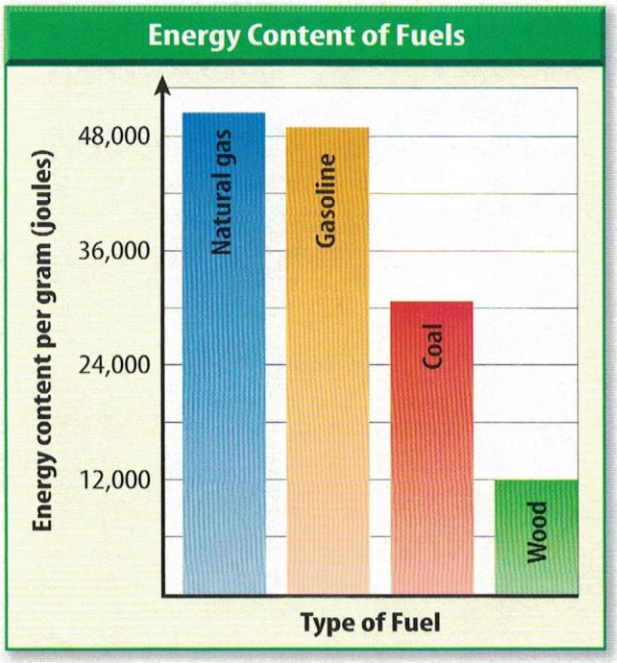
Figure 2 These circle graphs show where energy is used in the United States and sources of this energy.

Making Fossil Fuels

In one hour of freeway driving a car might use several gallons of gasoline. It may be hard to believe that it took millions of years to make the fuels that are used to produce electricity, provide heat, and transport people and materials. **Figure 4** on the next page shows how coal, petroleum, and natural gas are formed by the decay of ancient plants and animals. Fuels such as petroleum, or oil, natural gas, and coal are called **fossil fuels** because they are formed from the decaying remains of ancient plants and animals.

Concentrated Energy Sources When fossil fuels are burned, carbon and hydrogen atoms combine with oxygen molecules in the air to form carbon dioxide and water molecules. This process converts the chemical potential energy that is stored in the chemical bonds between atoms to heat and light. Compared to other fuels such as wood, the chemical energy that is stored in fossil fuels is more concentrated. For example, burning 1 kg of coal releases two to three times as much energy as burning 1 kg of wood. **Figure 3** shows the amount of energy that is produced by burning different fossil fuels.

Figure 3 The bar graph shows the amount of energy released by burning one gram of four different fuels. **Determine** *the ratio of the energy content of natural gas to the energy content of wood.*

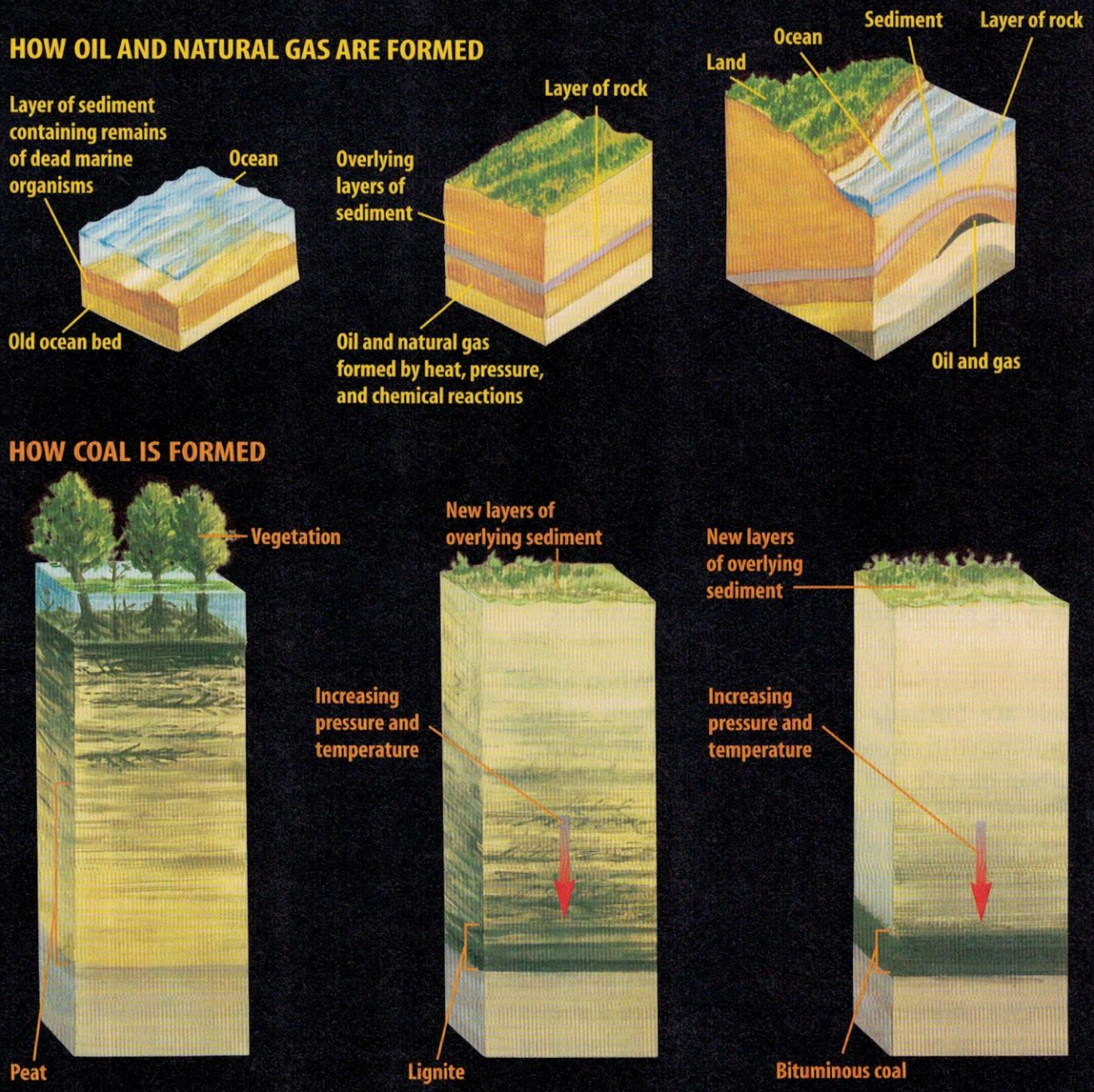


NATIONAL GEOGRAPHIC

VISUALIZING THE FORMATION OF FOSSIL FUELS

Figure 4

Oil and natural gas form when organic matter on the ocean floor, gradually buried under additional layers of sediment, is chemically changed by heat and crushing pressure. The oil and gas may bubble to the surface or become trapped beneath a dense rock layer. Coal forms when peat—partially decomposed vegetation—is compressed by overlying sediments and transformed first into lignite (soft brown coal) and then into harder, bituminous (buh TYEW muh nus) coal. These two processes are shown below.



Petroleum

Millions of gallons of petroleum, or crude oil, are pumped every day from wells deep in Earth's crust. **Petroleum** is a highly flammable liquid formed by decayed ancient organisms, such as microscopic plankton and algae. Petroleum is a mixture of thousands of chemical compounds. Most of these compounds are hydrocarbons, which means their molecules contain only carbon atoms and hydrogen atoms.

Separating Hydrocarbons The different hydrocarbon molecules found in petroleum have different numbers and arrangements of carbon and hydrogen atoms. The composition and structure of hydrocarbons determines their properties.

The many different compounds that are found in petroleum are separated in a process called fractional distillation. This separation occurs in the tall towers of oil-refinery plants. First, crude oil is pumped into the bottom of the tower and heated. The chemical compounds in the crude oil boil and vaporize according to their individual boiling points. Materials with the lowest boiling points rise to the top of the tower as vapor and are collected. Hydrocarbons with high boiling points, such as asphalt and some types of waxes, remain liquid and are drained off through the bottom of the tower.

Reading Check *What is fractional distillation used for?*

Other Uses for Petroleum Not all of the products obtained from petroleum are burned to produce energy. About 15 percent of the petroleum-based substances that are used in the United States go toward nonfuel uses. Look around at the materials in your home or classroom. Do you see any plastics? In addition to fuels, plastics and synthetic fabrics are made from the hydrocarbons found in crude petroleum. Also, lubricants such as grease and motor oil, as well as the asphalt used in surfacing roads, are obtained from petroleum. Some synthetic materials produced from petroleum are shown in **Figure 5.**

Mini LAB

Designing an Efficient Water Heater

Procedure

1. Measure and record the mass of a **candle.**
2. Measure 50 mL of **water** into a **beaker.** Record the temperature of the water.
3. Use the lighted candle to increase the temperature of the water by 10°C. Put out the candle and measure its mass again.
4. Repeat steps 1 to 3 with an **aluminum chimney** surrounding the candle to help direct the heat upward.

Analysis

1. Compare the mass change in the two trials. Does a smaller or larger mass change in the candle show greater efficiency?
2. Gas burners are used to heat hot-water tanks. What must be considered in the design of these heaters?

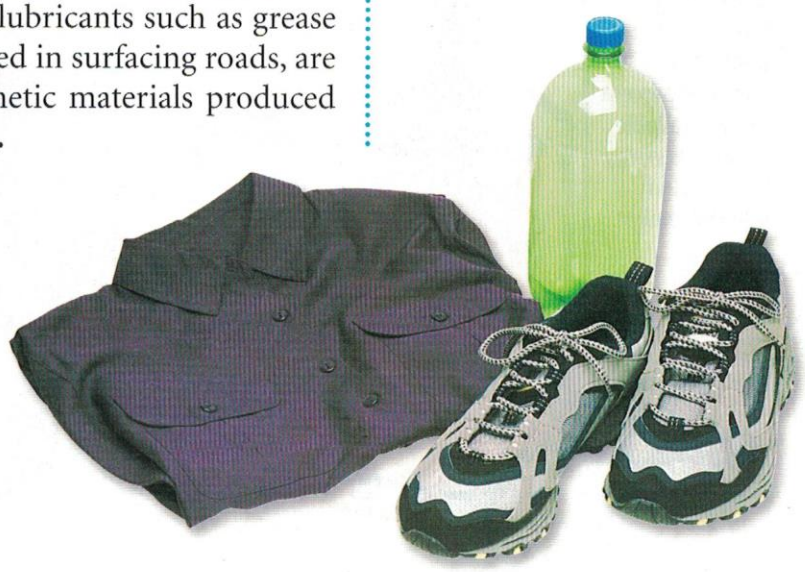


Figure 5 The objects shown here are made from chemical compounds found in petroleum.
Identify *four objects in your classroom that are made from petroleum.*

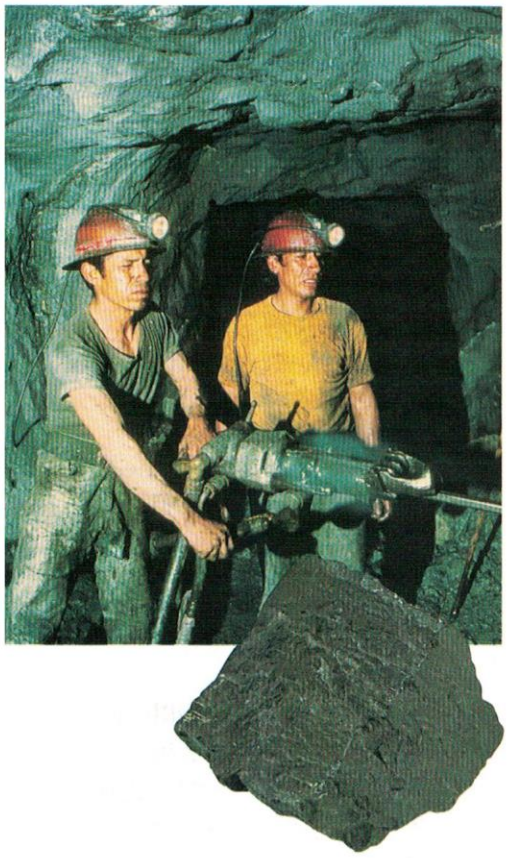


Figure 6 Coal mines usually are located deep underground.

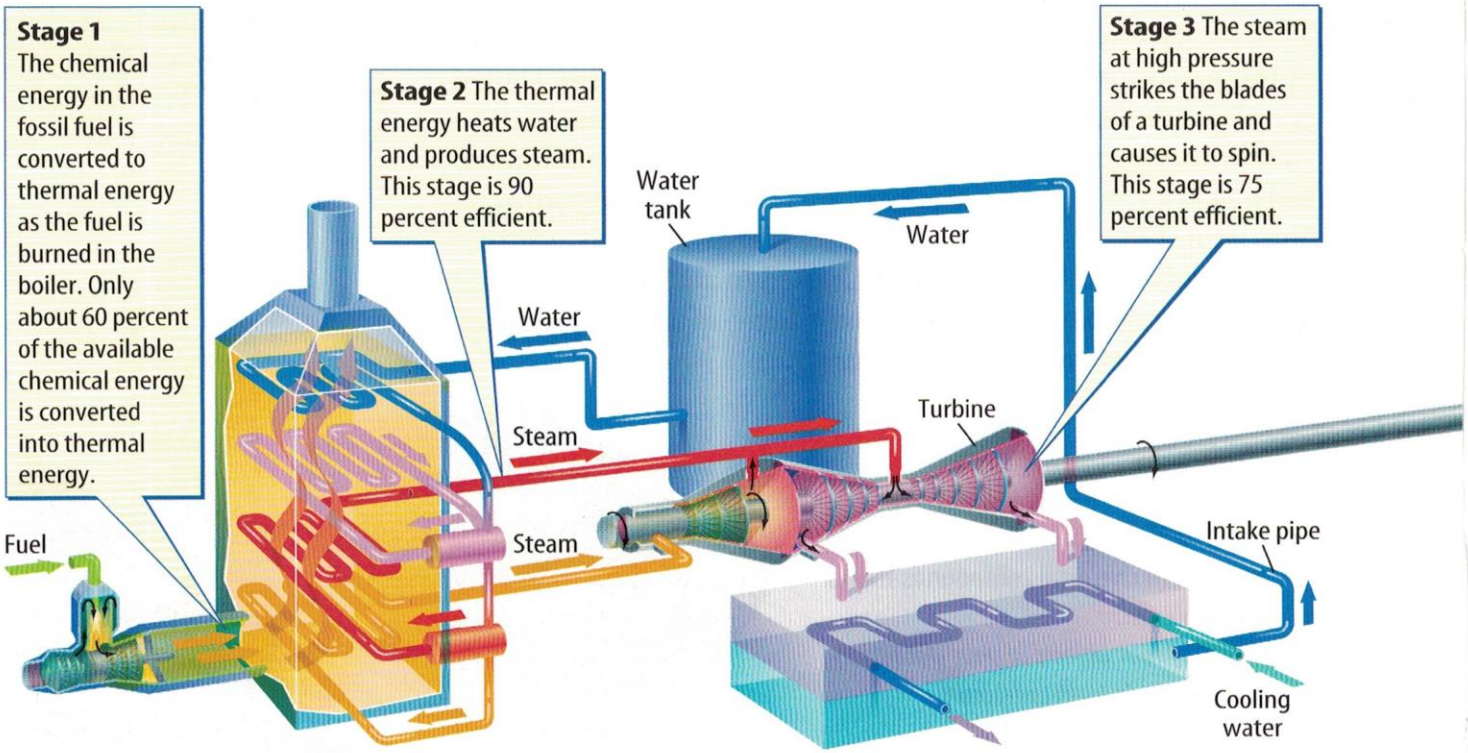
Natural Gas

The chemical processes that produce petroleum as ancient organisms decay also produce gaseous compounds called natural gas. These compounds rise to the top of the petroleum deposit and are trapped there. Natural gas is composed mostly of methane, CH_4, but it also contains other hydrocarbon gases such as propane, C_3H_8, and butane, C_4H_{10}. Natural gas is burned to provide energy for cooking, heating, and manufacturing. About one fourth of the energy consumed in the United States comes from burning natural gas. There's a good chance that your home has a stove, furnace, hot-water heater, or clothes drier that uses natural gas.

Natural gas contains more energy per kilogram than petroleum or coal does. It also burns more cleanly than other fossil fuels, produces fewer pollutants, and leaves no residue such as ash.

Coal

Coal is a solid fossil fuel that is found in mines underground, such as the one shown in **Figure 6.** In the first half of the twentieth century, most houses in the United States were heated by burning coal. In fact, during this time, coal provided more than half of the energy that was used in the United States. Now, almost two-thirds of the energy used comes from petroleum and natural gas, and only about one-fourth comes from coal. About 90 percent of all the coal that is used in the United States is burned by power plants to generate electricity.



Origin of Coal Coal mines were once the sites of ancient swamps. Coal formed from the organic material that was deposited as the plants that lived in these swamps died. Worldwide, the amount of coal that is potentially available is estimated to be 20 to 40 times greater than the supply of petroleum.

Coal also is a complex mixture of hydrocarbons and other chemical compounds. Compared to petroleum and natural gas, coal contains more impurities, such as sulfur and nitrogen compounds. As a result, more pollutants, such as sulfur dioxide and nitrogen oxides, are produced when coal is burned.

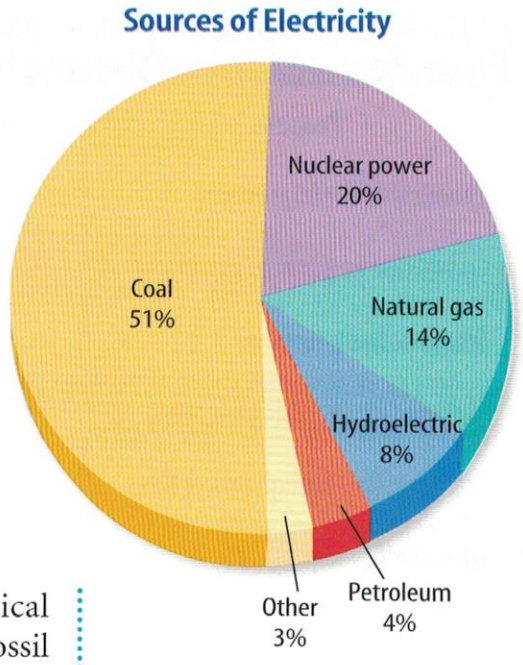
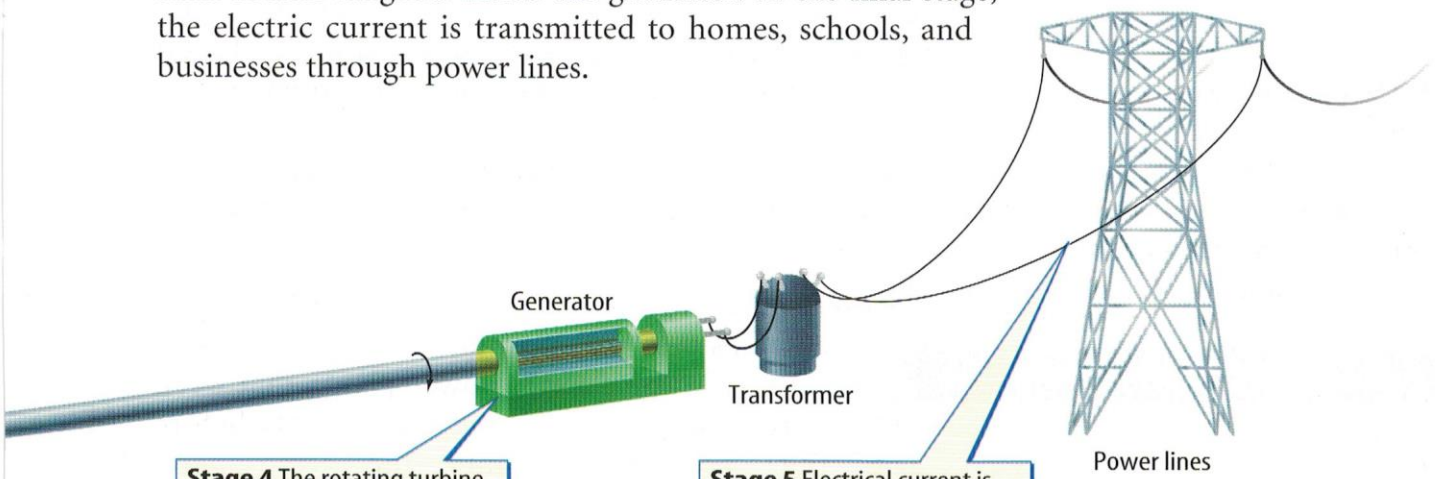


Figure 7 This circle graph shows the percentage of electricity generated in the United States that comes from various energy sources.

Generating Electricity

Figure 7 shows that almost 70 percent of the electrical energy used in the United States is produced by burning fossil fuels. How is the chemical energy contained in fossil fuels converted to electrical energy in an electric power station?

The process is shown in **Figure 8.** In the first stage, fuel is burned in a boiler or combustion chamber, and it releases thermal energy. In the second stage, this thermal energy heats water and produces steam under high pressure. In the third stage, the steam strikes the blades of a turbine, causing it to spin. The shaft of the turbine is connected to an electric generator. In the fourth stage, electric current is produced when the spinning turbine shaft rotates magnets inside the generator. In the final stage, the electric current is transmitted to homes, schools, and businesses through power lines.



Stage 4 The rotating turbine spins an electric generator. Ninety-five percent of the mechanical energy in the rotating turbine is converted into electrical energy.

Stage 5 Electrical current is transmitted along power lines. Electrical resistance converts some of the electrical energy to thermal energy. This stage is 90 percent efficient.

Figure 8 Fossil fuels are burned to generate electricity in a power plant. **Determine** *which stage in this process is the most inefficient.*

Table 1 Efficiency of Fossil Fuel Conversion

Process	Efficiency (%)
Chemical to thermal energy	60
Conversion of water to steam	90
Steam-turning turbine	75
Turbine spins electric generator	95
Transmission through power lines	90
Overall efficiency	35

Efficiency of Power Plants

When fossil fuels are burned to produce electricity, not all the chemical energy in the fuel is converted to electrical energy. In every stage of the process, some energy is converted into forms of energy that can't be used.

The overall efficiency of the entire process is given by multiplying the efficiencies of each stage of the process shown in **Table 1.** If you were to do this, you'd find that the resulting overall efficiency is only about 35 percent. This means that only about 35 percent of the energy contained in the fossil fuels is delivered to homes, schools, and businesses as electrical energy. The other 65 percent is converted mainly into thermal energy when the chemical energy in fuel is transformed into electrical energy that is delivered to energy users.

The Costs of Using Fossil Fuels

Although fossil fuels are a useful source of energy for generating electricity and providing the power for transportation, their use has some undesirable side effects. When petroleum products and coal are burned, smoke is given off that contains small particles called particulates. These particulates cause breathing problems for some people. Burning fossil fuels also releases carbon dioxide. **Figure 9** shows how the carbon dioxide concentration in the atmosphere has increased from 1960 to 2000. One consequence of increasing the atmospheric carbon dioxide concentration could be to cause Earth's surface temperature to increase.

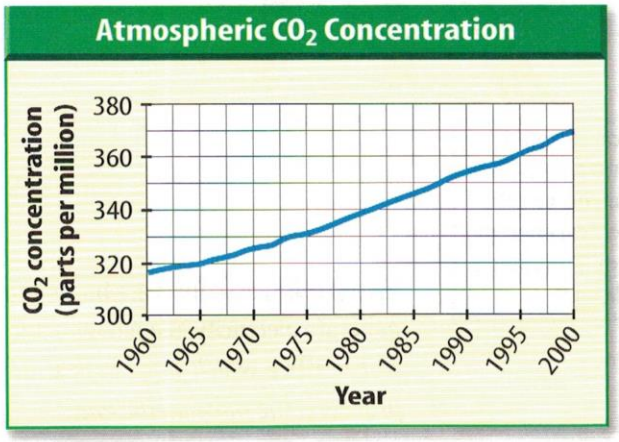


Figure 9 The carbon dioxide concentration in Earth's atmosphere has been measured at Mauna Loa in Hawaii. From 1960 to 2000, the carbon dioxide concentration has increased by about 16 percent.

Using Coal The most abundant fossil fuel is coal, but coal contains even more impurities than oil or natural gas. Many electric power plants that burn coal remove some of these pollutants before they are released into the atmosphere. Removing sulfur dioxide, for example, helps to prevent the formation of compounds that might cause acid rain. Mining coal also can be dangerous. Miners risk being killed or injured, and some suffer from lung diseases caused by breathing coal dust over long periods of time.