Nonrenewable Energy

CHAPTER 17

READING WARM-UP

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

1. You flip on a light switch, and the lights come on. Where do you think that the electricity that powers the light bulb comes from?
2. What do you think our major sources of energy will be 100 years from now? Explain your answer.

At this petroleum refinery in Germany, crude oil pumped from the Earth is changed into fuels, such as gasoline, and other products.

SECTION 1

Energy Resources and Fossil Fuels

How does a sunny day 200 million years ago relate to your life today? Chances are that if you traveled to school today or used a product made of plastic, you used some of the energy from sunlight that fell on Earth several hundred million years ago. Life as we know it would be very different without the fuels or products formed from plants and animals that lived alongside the dinosaurs.

The fuels we use to run cars, ships, planes, and factories and to produce electricity are natural resources. Most of the energy we use comes from a group of natural resources called *fossil fuels*. **Fossil fuels** are the remains of ancient organisms that changed into coal, oil, or natural gas. Fossil fuels are central to life in modern societies, yet there are two main problems with fossil fuels. First, the supply of fossil fuels is limited. Second, obtaining and using them has environmental consequences. In the 21st century, societies will continue to explore alternatives to fossil fuels but will also focus on developing more-efficient ways to use these fuels.

Objectives

- List five factors that influence the value of a fuel.
- Explain how fuels are used to generate electricity in an electric power plant.
- Identify patterns of energy consumption and production in the world and in the United States.
- Explain how fossil fuels form and how they are used.
- Compare the advantages and disadvantages of fossil-fuel use.
- List three factors that influence predictions of fossil-fuel production.

Key Terms

fossil fuels
electric generator
petroleum
oil reserves

Fuels for Different Uses

Fuels are used for four main purposes: for transportation, for manufacturing, for heating and cooling buildings, and for generating electricity to run machines and appliances. The suitability of a fuel for each application depends on the fuel's energy content, cost, availability, safety, and byproducts of the fuel's use. For example, it's hard to imagine an airplane, such as the one shown in **Figure 1**, running on piles of coal. Although coal is readily available and inexpensive, to power an airplane using coal would require hundreds of tons of coal. Likewise, the people shown around the campfire are not warming themselves by burning airplane fuel, they are burning wood, which is a perfect fuel for their needs.

Figure 1 ▶ Different Fuels, Different Purposes The airplane (left) is being refueled with a highly refined liquid fuel. Airplane fuel must have a high ratio of energy to weight. The campers (below) are keeping warm by burning wood, which is much safer than burning airplane fuel!

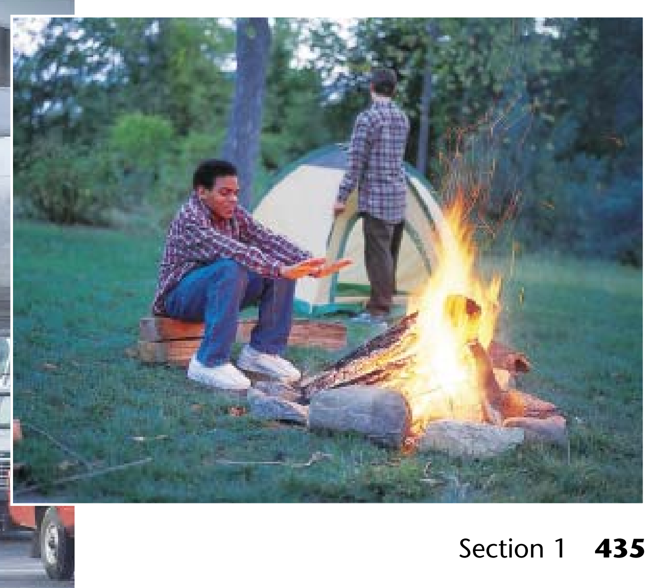


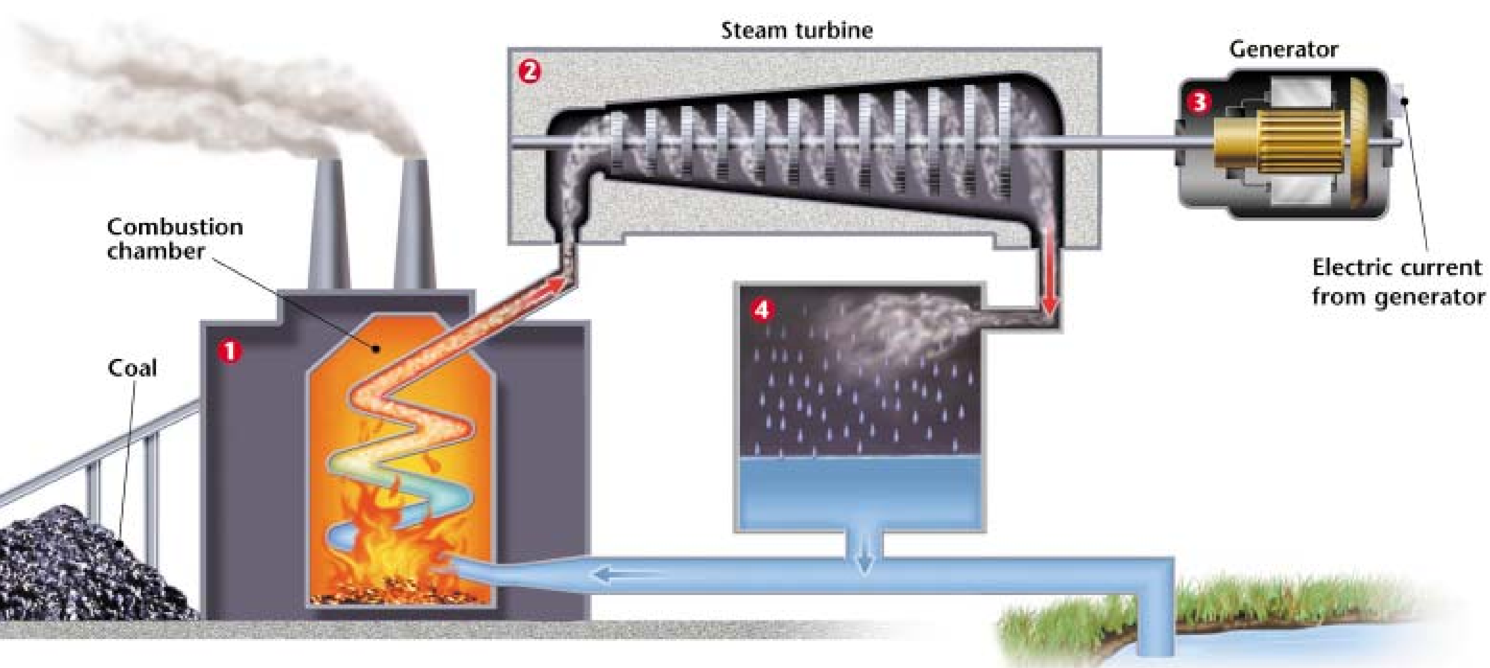
Figure 2 ▶ These pylons and wires are part of an electricity distribution grid in upstate New York.

Electricity—Power on Demand

The energy in fuels is often converted into electrical energy in order to power machines, because electricity is more convenient to use. Computers, for example, run on electricity rather than oil. Electricity can be transported quickly across great distances, such as an entire state, or across tiny distances, such as inside a computer chip. The electricity that powers the lights in your school was generated in a power plant and then carried to users through a distribution grid like the one shown in **Figure 2.** Two disadvantages of electricity are that it is difficult to store and other energy sources have to be used to generate it.

How Is Electricity Generated? An **electric generator** is a machine that converts mechanical energy, or motion, into electrical energy. Generators produce electrical energy by moving an electrically conductive material within a magnetic field. Most commercial electric generators convert the movement of a turbine into electrical energy, as shown in **Figure 3.** A *turbine* is a wheel that changes the force of a moving gas or a liquid into energy that can do work. In most power plants, water is boiled to produce the steam that turns the turbine. Water is heated by burning a fuel in coal-fired and gas-fired plants or is heated from the fission of uranium in nuclear plants. The turbine spins a generator to produce electricity.

Figure 3 ▶ **How a Coal-Fired Power Plant Works**

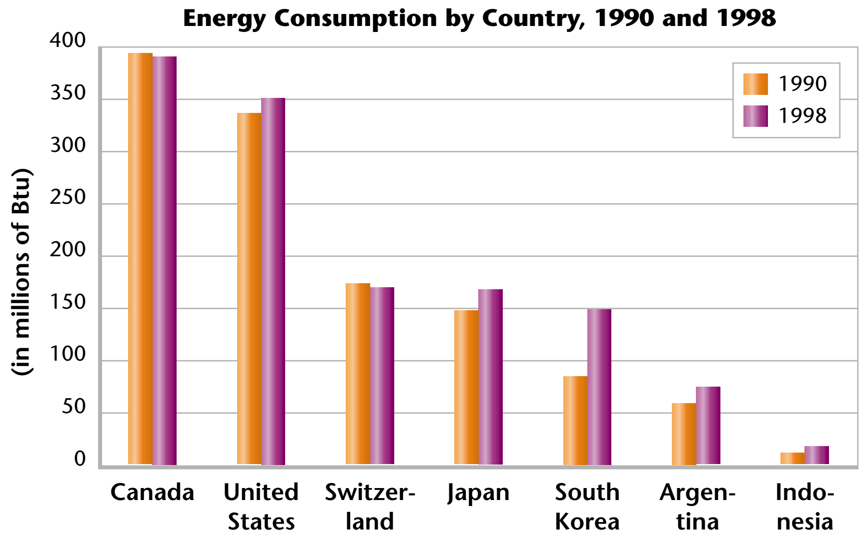


1 Burning fossil fuels release energy in the form of heat, which is used to boil water and produce high-pressure steam.

2 The steam is directed against the blades of a turbine, which is set into motion.

3 The turbine is connected to an electric generator. The turbine sets the generator in motion, generating electricity.

4 Steam from the turbine is directed to a condenser where it cools and becomes liquid water to be cycled again.



Source: U.S. Department of Energy.

Figure 4 ▶ Canada and Switzerland slightly reduced their energy use per person during this nine-year period, while energy use per person in South Korea increased by almost 50 percent.

Energy Use

Everything from the food you eat to the clothes you wear requires energy to produce. Furthermore, the price of nearly every product or service that you use reflects the cost of energy. When you purchase a plane ticket, for example, you purchase part of the fuel that will help you reach your destination. In 2000, airlines spent $5.4 billion on fuel—their second-highest expense after labor costs.

World Patterns There are dramatic differences in fuel use and efficiency throughout the world. People in developed societies use much more energy than people in developing countries do. However, energy use in some developing countries is growing rapidly. Even within the developed world there are striking differences in energy use. For example, **Figure 4** shows that a person in Canada or the United States uses more than twice as much energy as an individual in Japan or Switzerland does. Yet personal income in Japan and Switzerland is higher than personal income in Canada and the United States. One reason for this pattern lies in how energy is generated and used in those countries.

Energy Use in the United States The United States uses more energy per person than any other country in the world except Canada and the United Arab Emirates. Part of the reason that the United States uses so much energy is that, as **Figure 5** shows, the United States uses more than 25 percent of its energy resources to transport goods and people, mainly by trucks and personal vehicles. In contrast, Japan and Switzerland have extensive rail systems and they are relatively small, compact countries. The availability and cost of fuels also influence fuel use. Residents of the United States and Canada enjoy some of the lowest gasoline taxes in the world. There is little incentive to conserve gasoline when its cost is so low. Japan and Switzerland, which have minimal fossil-fuel resources, supplement a greater percentage of their energy needs with other energy sources, such as hydroelectric or nuclear power.

QuickLAB

Generating Electricity

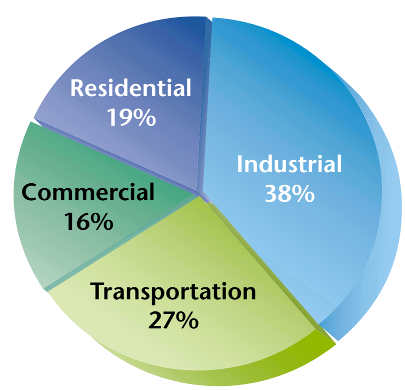
Procedure

1. Tightly wrap 100 cm of **fine-gauge copper wire** around a **small cardboard tube.**
2. Attach a **galvanometer** or a **battery tester** to the ends of the wire.
3. Pass a **bar magnet** through the cardboard tube, and observe the galvanometer.

Analysis

1. What did you observe?
2. How could you increase the current you detected?
3. How does this lab model an electric power plant?

How Energy Is Used in the United States



Source: International Energy Agency.

Figure 5 ▶ This graph shows the percentages of total energy use in the United States for different purposes.

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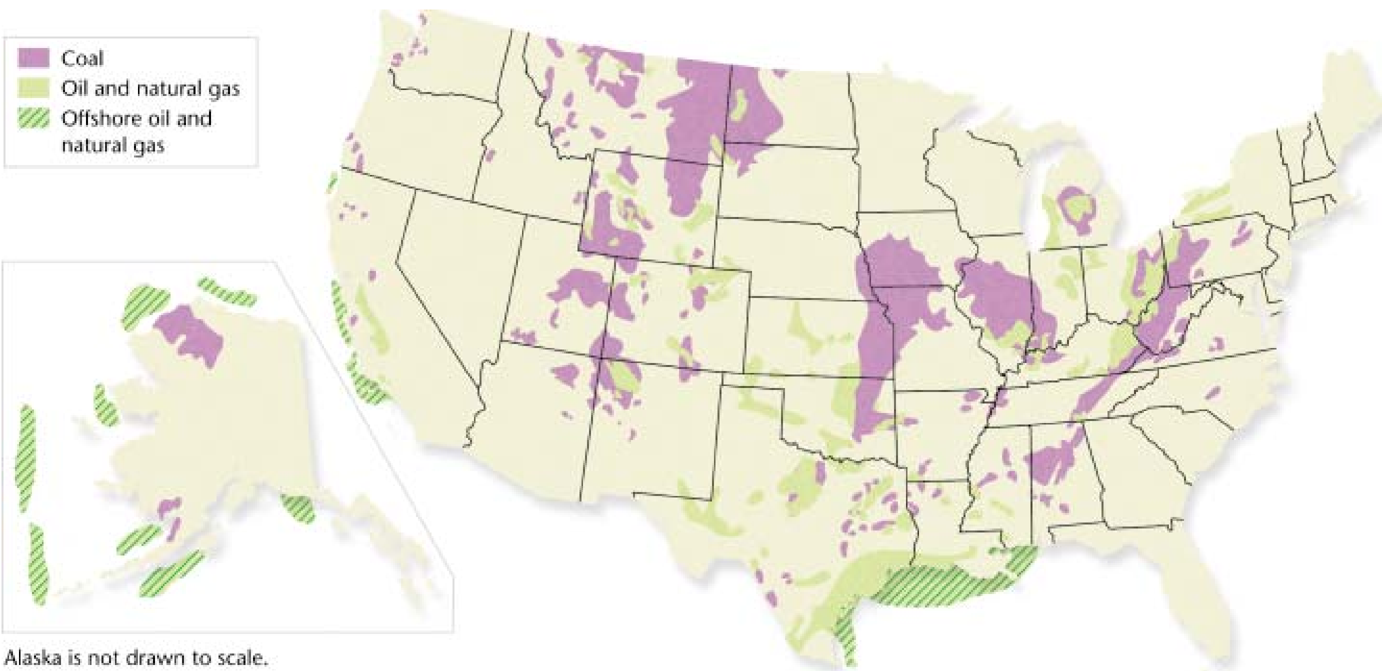
How Fossil-Fuel Deposits Form

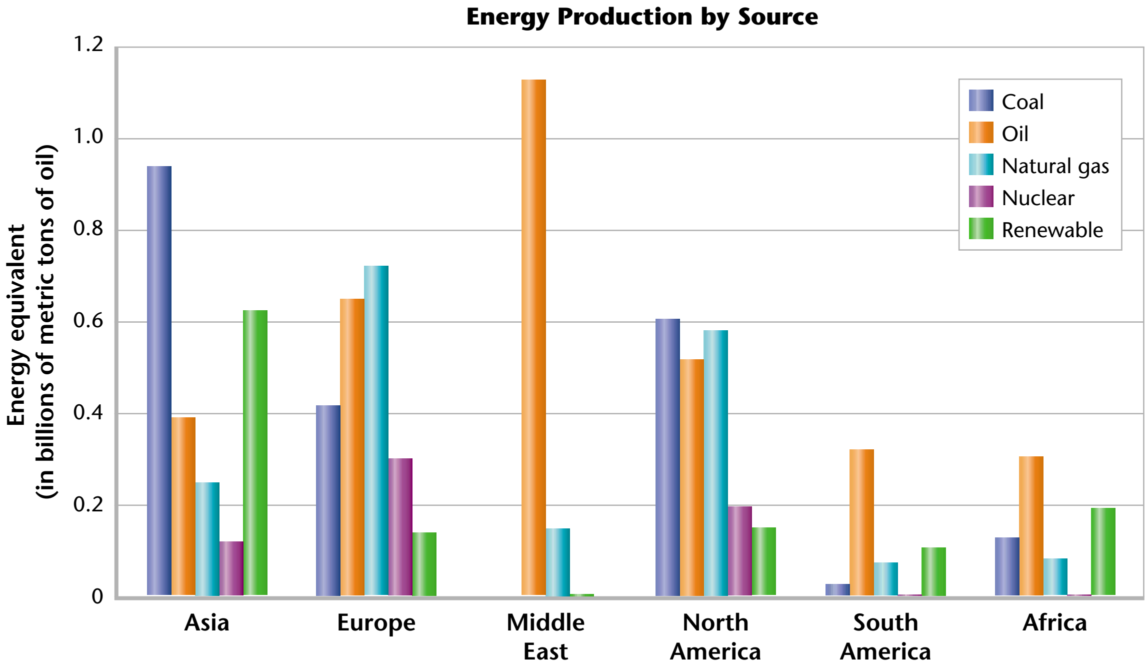
Fossil fuels are not distributed evenly, as shown in **Figure 6.** For example, why is there an abundance of oil in Texas and Alaska but very little in Maine? Why does the eastern United States produce so much coal? The answers to these questions lie in the geologic history of the areas.

Coal Formation Coal forms from the remains of plants that lived in swamps hundreds of millions of years ago. Much of the coal in the United States formed about 300 million to 250 million years ago, when vast areas of swampland covered the eastern United States. As ocean levels rose and fell, these swamps were repeatedly covered with sediment. Layers of sediment compressed the plant remains, and heat and pressure within the Earth's crust caused coal to form. Coal deposits in the western United States also formed from ancient swamps, but those deposits are much younger. The abundant coal deposits in states such as Wyoming formed between 100 million and 40 million years ago.

Oil and Natural Gas Formation Oil and natural gas result from the decay of tiny marine organisms that accumulated on the bottom of the ocean millions of years ago. After these remains were buried by sediments, they were heated until they became complex energy-rich carbon molecules. Over time, these molecules migrated into the porous rock formations that now contain them. Much of the oil and natural gas in the United States is located in Alaska, Texas, California, and the Gulf of Mexico.

Figure 6 ▶ This map shows coal, oil, and natural gas deposits in the United States.





Source: International Energy Agency.

Figure 7 ▶ The Middle East produces the majority of the world's oil. Asia, however, produces the most coal.

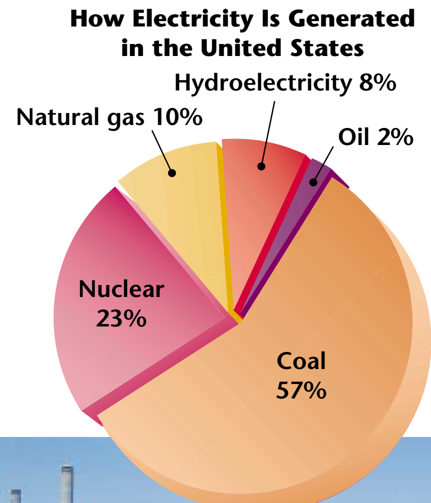
Coal

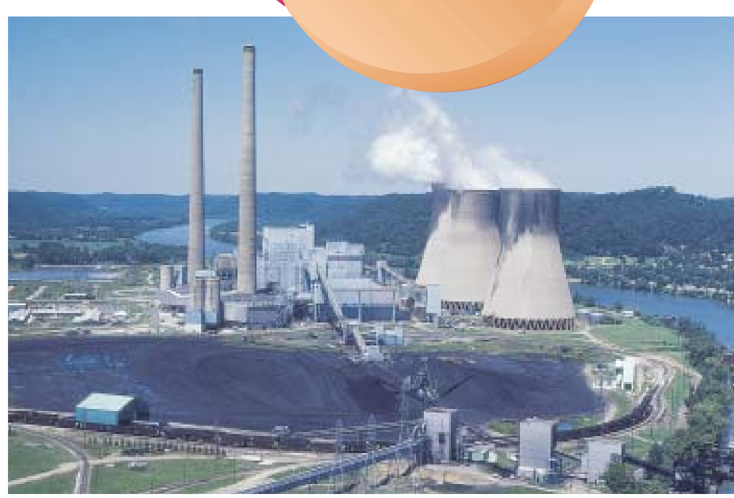
Most of the world's fossil-fuel reserves are made up of coal. Asia and North America are particularly rich in coal deposits, as shown in **Figure 7.** Two major advantages of coal are that it is relatively inexpensive and that it needs little refining after it has been mined. More than half of the electricity generated in the United States comes from coal-fired power plants, as shown in **Figure 8.**

Coal Mining and the Environment The environmental effects of coal mining vary. Underground mines can have a minimal effect on the environment at the surface. However, surface coal-mining operations sometimes remove the top of an entire mountain to reach the coal deposit. In addition, if waste rock from coal mines is not properly contained, toxic chemicals can leach into nearby streams. A lot of research focuses on developing better methods of locating the most productive, clean-burning coal deposits and developing less damaging methods of mining coal.

Air Pollution The quality of coal varies. Higher-grade coals, such as bituminous coal, produce more heat and less pollution than a lower-grade coal, such as lignite. Sulfur, which is found in all grades of coal, can be a major source of pollution when coal is burned. When high-sulfur, low-grade coal is burned, it releases much more pollution than a low-sulfur bituminous coal does. The air pollution and acid precipitation that result from burning high-sulfur coal without adequate pollution controls are serious problems in countries such as China. However, clean-burning coal technology has dramatically reduced air pollution in countries such as the United States.

Figure 8 ▶ More than half of the electricity generated in the United States comes from burning coal. This power plant (bottom) in West Virginia is located close to the abundant coal deposits in that state.





Connection to Chemistry

Catalytic Converters Catalytic converters are one of the most important emission-control features on cars. These devices use two separate catalysts—a *reduction catalyst* and an *oxidation catalyst*. The reduction catalyst uses platinum and rhodium to separate nitrous oxides, forming nitrogen and oxygen molecules. The oxidation catalyst uses platinum and palladium to burn—or oxidize—hydrocarbons and carbon monoxide, forming carbon dioxide, which is less harmful.

Petroleum

Oil that is pumped from the ground is also known as *crude oil,* or **petroleum.** Anything that is made from crude oil, such as fuels, chemicals, and plastics, is called a *petroleum product*. Much of the world's energy needs are met by petroleum products. In fact, petroleum accounts for 45 percent of the world's commercial energy use.

Locating Oil Deposits Oil is found in and around major geologic features that tend to trap oil as it moves in the Earth's crust. These features, which include folds, faults, and salt domes, are bound by impermeable layers of rock, which prevent the oil from escaping. Most of the world's oil reserves are in the Middle East. Large oil deposits also exist in the United States, Venezuela, the North Sea, Siberia, and Nigeria. Geologists use many different methods to locate the rock formations that could contain oil. When geologists have gathered all of the data that they can from the Earth's surface, exploration wells are drilled to determine the volume and availability of the oil deposit. If oil can be extracted at a profitable rate, wells are drilled and the oil is pumped or flows to the surface. After petroleum is removed from a well, it is transported to a refinery to be converted into fuels and other petroleum products.

CASE STUDY

Methane Hydrates— Fossil Fuel of the Future?

Deep under the waves in the Gulf of Mexico lies an untapped resource that could be the fuel of the future. It looks like ice, but it burns with a bright fire. This strange compound is called methane hydrate.

A methane hydrate is a cagelike lattice of ice that contains trapped molecules of methane. Methane is a natural gas made up of carbon and hydrogen. The methane in methane hydrates results from the bacterial decomposition of organic matter.

Methane hydrates have been known to exist since 1890. However, nobody knew that the hydrates formed in nature until 1964, when a large deposit was discovered by a Soviet crew that was drilling for oil in Siberia. Today, huge deposits of this "solid" natural gas have been discovered around the edges of most continents. The deposits are often several hundred meters thick.

Methane hydrates form in geologic situations in which temperatures are stable and low and pressure is high. In places such as Siberia and Alaska, methane hydrates form below the tundra where permafrost extends down into shallow sediments. They also form under the ocean in water that is deeper than 500 m. In the United States, there are deposits of methane hydrates off the shores of Alaska, Washington, California, and the Carolinas and in the Gulf of Mexico. If we could recover just one percent of the methane hydrate around the United States we could more than double our supply of natural gas, a clean-burning fuel that produces little pollution except for carbon dioxide.

Natural gas is in increasing demand for use in new electric power stations. These power stations are cheaper to build than other power stations and produce little air pollution. Natural gas is also used to fuel low-pollution vehicles.

Natural gas will become an increasingly important substitute for coal and petroleum as countries limit their emissions of the greenhouse

The Environmental Effects of Using Oil When petroleum fuels are burned, they release pollutants. Internal combustion engines in vehicles that burn gasoline pollute the air in many cities. These pollutants contribute to the formation of smog and cause health problems. Emissions regulations and technology such as catalytic converters have reduced air pollution in many areas. However, in developing countries, cars are generally older, and the gasoline that they burn contains significantly more sulfur, a pollutant that contributes to acid precipitation. Many scientists also think that the carbon dioxide released from burning petroleum fuels contributes to global warming.

Oil spills, such as the one shown in **Figure 9,** are another potential environmental problem of oil use. In recent years, new measures have been taken to prevent oil spills from tankers. These measures include requiring that new tankers be double-hulled so that puncturing the outer hull does not allow the oil to leak out. Also, response times to clean up oil spills have improved. While oil spills are dramatic, much more oil pollution comes from everyday sources, such as leaking cars. However, measures to reduce everyday contamination of our waterways from oil lag far behind the efforts made to prevent large spills.

Figure 9 ▶ This ship is attempting to contain the oil spilled from the *Sea Empress* in 1996.

▶ A researcher holds a chunk of burning methane hydrate (far left). A methane hydrate mound in the Gulf of Mexico (left).

gas carbon dioxide to reduce global warming. As a result, the use of fuel-cell technology in vehicles will also increase. Fuel cells need hydrogen as a power source, and natural gas is a convenient source of hydrogen. The first fuel-cell vehicles will probably be fueled at a gas station that also has a natural gas pump.

So far, we have no technology to recover or use this strange mixture of ice and methane. One potential idea is to pump heated water into a methane hydrate deposit to melt the ice and release the methane gas. The gas would then have to be pumped to a processing plant.

CRITICAL THINKING

1. Applying Processes What are the differences between the geologic processes by which petroleum and natural gas form and the way methane hydrates form?

2. Analyzing Relationships Methane is a very effective greenhouse gas. How might this factor into the extraction or use of methane hydrates in the future?

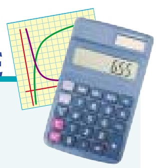
Figure 10 ▶ Except when it is refueling, a vehicle that runs on natural gas looks like one that runs on gasoline.

Natural Gas About 20 percent of the world's nonrenewable energy comes from natural gas. Natural gas, or methane (CH_4), is a good example of how advances in technology can make a fuel more common. In the past, when natural gas was encountered in an oil well, it was burned off because it was considered a nuisance. As technology improved, transporting natural gas in pipelines and storing it in compressed tanks became more practical. Now, many more oil wells recover natural gas. Because burning natural gas produces fewer pollutants than other fossil fuels, vehicles that run on natural gas, such as the one in **Figure 10,** require fewer pollution controls. Electric power plants can also use this clean-burning fuel.

Fossil Fuels and the Future

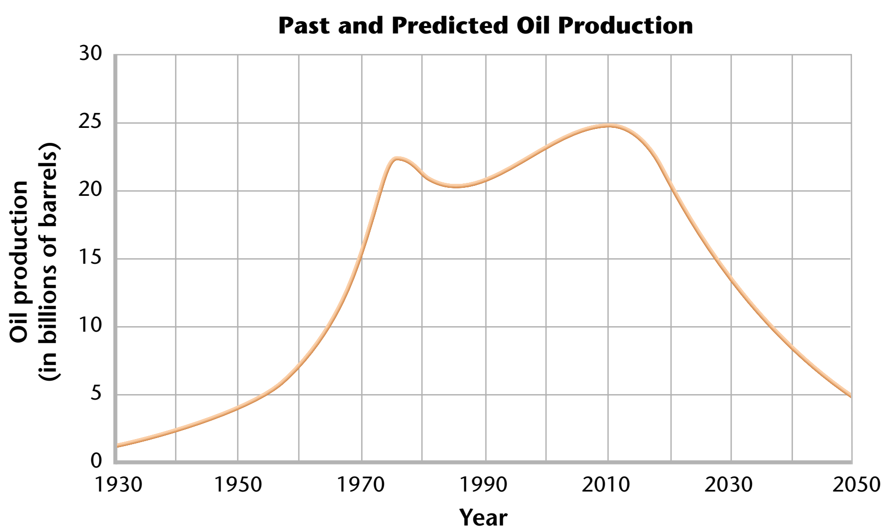
Today, fossil fuels supply about 90 percent of the energy used in developed countries. Some projections suggest that by 2050 world energy demand will have doubled, mainly as a result of increased population and industry in developing countries. As the demand for energy resources increases, the cost of fossil fuels will likely increase enough to make other energy sources more attractive. Planning now for the energy we will use in the future is important because it takes many years for a new source of energy to make a significant contribution to our energy supply.

MATHPRACTICE



World Energy Use
In 1980, worldwide production of petroleum was 59.6 million barrels per day. In 1998, petroleum production was 66.9 million barrels a day. Calculate the percent increase in oil production during this period.

Predicting Oil Production Oil production is still increasing, but it is increasing much more slowly than it has in the past, as shown in **Figure 11.** Many different factors must be considered when predicting oil production. Oil reserves are oil deposits that can be extracted profitably at current prices using current technology. In contrast, some oil deposits are yet to be discovered or to become commercial. Predictions must also take into account changes in technology that would allow more oil to be extracted in the future.



Source: Petroconsultants S.A.

Figure 11 ▶ This graph shows past oil production and one prediction for the future.

Finally, all predictions of future oil production are guided by an important principle: the relative cost of obtaining fuels influences the amount of fossil fuels that we extract from the Earth. For example, as the supply of readily available oil decreases, we may begin to rely less on oil reserves and focus on using oil more selectively. At that time, oil will begin to be used more for applications in which it is essential. Cars and power plants, which can be powered in many ways, will begin to rely on other energy sources.

Future Oil Reserves No large oil reserves have been discovered in the past decade, and geologists predict that oil production from fields accessible from land will peak in about 2010. Additional oil reserves are under the ocean, but extracting oil from beneath the ocean floor is much more expensive. Currently, oil platforms can be built to drill for oil at depths greater than 1,800 m, but much of the oil in the deep ocean is currently inaccessible. Deep-ocean reserves may be tapped in the future, but unless oil-drilling technology improves, oil from the deep ocean will be much more expensive than oil produced on land.

Connection to Astronomy

Cosmic Oil Some scientists support a controversial hypothesis that some oil and natural gas deposits did not come from the remains of ancient life but were incorporated into the Earth during its formation from the solar nebula 4.5 billion years ago. Hydrocarbons are some of the most common compounds in the universe and large amounts of them could have been incorporated in the Earth as it formed. If this theory is correct, the Earth could contain vast reserves of "cosmic fossil fuels" that are not yet discovered.

Figure 12 ▶ This offshore oil rig is extracting petroleum from beneath the ocean floor.

SECTION 1 Review

1. **Describe** five factors that influence the value of a fuel.
2. **Describe** how fossil fuels are used to produce electricity, and explain how an electric generator works.
3. **Describe** how coal, oil, and natural gas form, how these fuels are used, and how using each fuel affects the environment.

CRITICAL THINKING

4. **Analyzing Relationships** What is the relationship between natural gas and petroleum?
5. **Making Comparisons** Read the description of how fossil-fuel deposits form. Are fossil fuels produced today by the same geologic processes as in the past? READING SKILLS
6. **Making Inferences** Examine Figure 11. What do you think accounts for the dramatic increase in the worldwide production of oil after 1950?