“**DOWN BY THE STATION,** early in the morning, see the little pufferbellies all in a row.” When you hear that old children’s song, do you ever wonder what a pufferbelly is? *Pufferbelly* is a slang term for a steam locomotive. Many years ago, railroad trains were powered by steam, and that steam usually came from water heated by burning coal.

Today most trains run on diesel fuel or electricity, not steam produced by coal fires. Both diesel fuel and the coal that powered the old steam locomotives are fossil fuels. All fossil fuels are nonrenewable energy resources. These nonrenewable fuels were produced by processes that are still happening today. However, these processes do not create fossil fuels nearly fast enough to replace the ones we are using up. To replenish all the fossil fuels we have used so far would take many millions of years.

**How Fossil Fuels Form**

- **Fossil fuels form from the remains of organisms that lived millions of years ago.**

Fossil fuels, including coal, oil, and natural gas, are formed from the remains of once-living organisms. The energy in these fuels comes originally from the sun. During photosynthesis, electromagnetic energy from the sun is converted to chemical energy stored in complex molecules. Over millions of years, some of these molecules undergo a series of changes that eventually result in fossil fuels. Fossil fuels are composed mostly of hydrocarbons. Hydrocarbons are chemical compounds made mainly of hydrogen and carbon atoms.

**Breakdown Without Oxygen** After they die, most organisms do not end up as part of a coal, gas, or oil deposit. Fossil fuels are produced only when the remains of living things are broken down in an environment that has little or no oxygen, such as the bottoms of deep lakes, swamps, and shallow seas. As dead organisms gradually accumulate at the bottoms of these bodies of water, sediments may accumulate on top of the remains and exert pressure on them.
**Different Conditions, Different Fuels**  The remains of organisms may be converted into crude oil, natural gas, or coal. Various factors, such as temperature, amount of pressure, and the chemical composition of the starting material, determine which fossil fuels are produced. Oil, for example, comes from the remains of organisms such as microscopic animals and algae. These organisms live in oceans and inland seas. Coal forms from plant remains that are compressed under very high pressure. **Figure 6** shows how coal forms. First, peat forms as plants die and fall into a lake, bog, or swamp. Then, coal forms over millions of years, under increasing heat and pressure. Notice that there are different types of coal. Lignite has the lowest energy value, and anthracite typically has the highest.

**Coal**

Coal, which is used mainly to generate electricity, is obtained by mining.

Coal is the world’s most abundant fossil fuel, and its use goes back to ancient times. People in parts of China have heated with coal for at least 2000 years. In Britain, during the second and third centuries of the modern era, the ancient Roman invading armies used coal for heating. Beginning in the 1300s, in what is now the southwestern part of the United States, Native Americans of the Hopi Nation used coal to heat their homes, cook food, and fire pottery.

North America has abundant coal reserves. One quarter of the world’s coal is located in the United States. Asia, too, is rich in coal. Today, China and the United States are the main producers and users of coal.

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**Can we depend on nonrenewable energy resources for our energy needs?**

**Explanation** After students have read about coal formation, help them use what they have learned to expand their understanding of the Big Question. First, have students write a sentence that relates the length of time required for coal to form to coal’s classification as a nonrenewable energy resource. Then, have students apply their knowledge of coal formation to develop and support an opinion about whether people can use nonrenewable energy resources for all of their energy needs.

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**Reading Checkpoint** What nations are the main producers and users of coal today?
How Coal Is Used  Coal provides one fourth of the world's energy. Coal-fired steam engines helped drive the Industrial Revolution, powering factories, trains, and ships. In the 1880s, people began to use coal to generate electricity. Today, coal generates about half the electricity used by Americans. In addition, coal powers many industries. Some of these industries are chemical manufacturing, iron and steel manufacturing, and paper mills.

Mining for Coal  We use two major methods to remove coal from the ground. Look at Figure 7 as you read about these methods.

▶ Strip Mining  When coal deposits are at or near the surface, strip mining is used. Strip mining is the extraction of a mineral by removing a strip of the layers of soil and rock on top of the mineral deposit. Strip mining may remove huge amounts of soil and rock. Once the coal is exposed, it can be extracted. After the coal has been removed, the soil may be put back to fill the holes. Strip mining operations can extend over a large area. In some cases, entire mountaintops are blasted away.

▶ Subsurface Mining  We reach underground deposits with subsurface mining. Subsurface mining is typically the practice of digging shafts deep into the ground to find and remove a mineral. Networks of tunnels are usually blasted with explosives and then dug out so that miners can reach the coal. After miners dig the coal out, it is brought to the surface.

Advantages of Coal  There are several reasons why coal is used commonly as an energy source. Compared to other fossil fuels, coal is more abundant and less expensive. It does not need much processing after it has been removed from the ground. Coal can be transported relatively easily in trucks and trains. Unlike the oil taken from Prudhoe Bay in Alaska, coal does not require a pipeline.

Find Out More  Answers will vary, but should indicate that students have used reliable resources to learn more about heating methods used in their houses or apartments.
Oil

Petroleum, which is obtained by drilling, is a major source of energy and is used to make a variety of products.

Oil, or petroleum, is a dark, liquid fossil fuel made up mostly of hydrocarbons. Petroleum is found in underground deposits. The Middle East is especially rich in these deposits. Petroleum is also found in other parts of the world, such as Russia, and North and South America.

How Petroleum Is Used  Petroleum is the source of the fuels used for most forms of transportation, such as cars, trucks, airplanes, and ships. Many people heat their homes with fuel oil. Because oil is a complex mix of hydrocarbons, it can be used to make many types of products. Petrochemicals are chemical compounds that are derived from oil and used to make products. Figure 8 shows some petroleum products that are used in and around a home.

Finding Petroleum Deposits  Most oil deposits are deep underground. There, the oil is usually found within tiny pores, or holes, in rocks such as sandstone and limestone. Rocks containing oil are a little bit like a sponge that has soaked up water. Scientists look for oil by performing various tests. For example, they send sound waves deep underground and determine how long it takes the waves to be reflected and to reach different surface locations. The length of time can indicate the characteristics of the rocks the waves pass through. Once scientists find a likely location, oil companies drill deep holes and remove rock cores to see whether the rocks contain oil.

What is petroleum composed of?

ANSWERS

Reading Checkpoint  Petroleum is composed mostly of hydrocarbons.

FIGURE 8 Petroleum Products
Many products, such as those shown here, are derived from petroleum.
Drilling for Oil  You squeeze a sponge to remove the water. Similarly, pressure is needed to get oil from porous rock. Usually, oil trapped in rocks is already under pressure. So at first, oil will rise in the well, often all the way to the surface, without needing to be pumped out. During that period, a process called primary extraction can be used to remove the oil, as shown in Figure 9.

Later, once the pressure decreases, oil companies use a process called secondary extraction to get the oil to the surface. In secondary extraction, chemicals may be used to dissolve oil. Secondary extraction may also involve pumping water, steam, or gases such as carbon dioxide beneath oil deposits to force the oil to the surface. At Prudhoe Bay in Alaska, seawater is piped into wells to flush out oil. Oil drilling takes place not just on land but on the seafloor in relatively shallow water.

Refining Oil  Oil taken out of the ground is called crude oil. Crude oil cannot be used the way it is. It must be refined in order to be usable. Refining involves separating crude oil into different fuels and other substances. This process takes place in a refinery.

Describe primary extraction.

Natural Gas

Natural gas yields a large amount of energy and is less polluting than other fossil fuels.

Natural gas consists of the gas methane mixed in with small amounts of other gases. Its use is growing faster than that of most other fossil fuels today. Natural gas is colorless and odorless. It is much less polluting than coal or oil, and it emits less carbon dioxide per unit of energy produced than either coal or oil. Natural gas produces a large amount of energy. Pockets of natural gas are often located above oil deposits, both on land and offshore. Coal deposits, too, may have natural gas above them. Within the United States, pipelines carry natural gas from its source to where it is used. If laid end to end, our network of natural gas pipelines would go to the moon and back twice.

About half the homes in the United States are heated by natural gas, as are many businesses. Appliances such as water heaters, stoves, and clothes dryers may use natural gas to produce heat. Increasingly, natural gas is used to generate electricity, because it does not pollute the atmosphere to the extent that coal does. Natural gas goes into products such as paints, plastics, dyes, and fertilizers.
The Supply of Fossil Fuels

The supply of fossil fuels is limited.

Global consumption of coal, oil, and natural gas has risen steadily for years, and it continues to rise. **Figure 10** shows this trend. Right now, all the coal, oil, and natural gas that will be available to human society have already formed. What will happen when easily obtainable supplies of fossil fuels begin to run out?

**Dwindling Deposits** No one knows the exact amount of fossil fuels that are left or how long they will last. The most accessible reserves of natural gas, oil, and coal have already been used up. Remaining deposits of fossil fuels are often difficult and expensive to extract. The technology for extracting and producing fossil fuels will probably continue to improve. However, as people continue to remove fossil fuels, it is becoming harder and harder to find new sources.

Some scientists and oil-industry experts calculate that we have already extracted nearly half of the world’s oil reserves. Many scientists predict that the worldwide production of oil will decrease over the next few decades. **Figure 11** shows a graph of one prediction for what will happen to oil production. And many scientists and experts think that we will face a crisis long before the last drop of oil is pumped from a well. If the demand for oil continues to increase, there will be a shortage when the rate of oil production first starts going down. Reserves of coal are expected to last significantly longer than oil. In fact, one projection indicates that coal supplies will last 130 years in the United States. But even supplies of coal, the most abundant fossil fuel, will not last forever.

**FIGURE 10** Consumption of Fossil Fuels

The graph shows how the use of petroleum, coal, and natural gas increased between 1980 and 2006.

**FIGURE 11** Oil Production

The graph shows how much oil has been produced worldwide since 1930 and one prediction for the amount of oil to be produced in the future.

**Connect to the Central Case**

**FIGURE 11 Oil Production** The graph shows how much oil has been produced worldwide since 1930 and one prediction for the amount of oil to be produced in the future. **Interpret Graphs** Does this graph affect your opinion about drilling in the Arctic Refuge? Explain your answer.
New Sources of Fossil Fuels  Are there other fossil fuels that can replace or supplement oil, natural gas, and coal? Oil sands, oil shale, and methane hydrate may be alternative sources of fossil fuels.

**Oil Sands**  Oil sands are deposits of moist sand and clay containing bitumen. Bitumen is a thick, heavy form of petroleum that is rich in carbon. Oil sands are generally removed by strip mining. After extraction, bitumen is refined into a more valuable synthetic crude oil. Petroleum prices are rising, and this fact makes oil sands more profitable than they once were.

**Oil Shale**  Oil shale is rock filled with a mixture of hydrocarbons. Once mined, oil shale can be burned directly, like coal. Alternatively, it can be processed to extract liquid petroleum. The world’s known deposits of oil shale may be able to produce a large amount of oil. As crude oil prices rise, oil shale is attracting a large amount of attention.

**Methane Hydrate**  The deep ocean floor contains a possible source of energy, methane hydrate. Methane hydrate is an icelike solid that consists of molecules of methane within a crystal network of water molecules. Methane hydrate can be burned to release energy. Scientists think there is a huge amount of methane hydrate on Earth. However, they still need to find a way to extract methane hydrate safely, without causing underwater landslides.

**Drawbacks**  Alternative fossil fuels are abundant, but they will not solve our energy challenges. They are expensive to extract and process. Because it takes a lot of energy to extract alternative fossil fuels, they provide much less net energy than conventional fossil fuels do. *(Net energy* is the energy provided by a source after the energy used to obtain the source has been subtracted.) In addition, the extraction of alternative fossil fuels can cause environmental damage. For example, strip mining is used to extract oil sands and oil shale, and strip mining removes topsoil and vegetation. The most serious environmental effect of these fuels is that their combustion releases greenhouse gases. Therefore, the use of these fuels would speed up climate change.