3

Nonrenewable Sources of Energy

Basic Concepts

- Name three nonrenewable sources of energy.
- List the characteristics of the different types of coal.
- State what synfuels are and why they may be important in the future.
- Define the Organization of Petroleum Exporting Countries (OPEC) and the relationship of the United States with the OPEC.
- Identify basic environmental concerns associated with the use of fossil fuels.

Intermediate Concepts

- Recognize the major components of a coal-fired generating plant.
- Explain the purpose of a fractionating tower.
- Give examples of some positive and negative impacts of importing oil.

Advanced Concepts

- Discuss various influences, including economic, environmental, technological, and political influences, with regard to the use and continued development of fossil fuels.

Nonrenewable energy sources are those sources you cannot replace once they have been used. Examples of nonrenewable energy sources are coal, oil, natural gas, and uranium. Over 90% of our energy needs are met by using these few sources of energy. America's heavy dependence on the automobile as a primary means of transportation is a major reason we are so heavily dependent on nonrenewable resources, especially oil. Nonrenewable energy sources can be divided up into two different groups: fossil fuels and uranium. Uranium will be covered in Chapter 4.

Fossil Fuels

Natural gas: Gas usually found within the vicinity of petroleum reserves.

The three primary fossil fuels are coal, oil, and natural gases. These come from the ground. Fossil fuels are formed by the decays of plants and animals. These decays have been buried in the ground for millions of years. The remains of such plants and animals have gradually built up in layers over the years. Over time, soil is piled on top of the deposits. Fossil fuels burn easily. See **Figure 3-1.** One main use for them is to heat homes and other buildings.

Figure 3-1. Coal burns easily and continues to be used for home heating, although it has been replaced in many areas by natural gas and heating oil. (Quaker State Oil Refining Corporation)

Fossil fuels come in the form of solids, such as coal. They can also be in the form of liquids or semisolids, which include petroleum and tar. Another form of fossil fuel is a gas. Gases are usually found within the vicinity of petroleum reserves. This type of gas is called ***natural gas***. Since fossil fuels are nonrenewable, they are decreasing in our environment. In a developed nation like the United States, it takes great quantities of fossil fuel to maintain our technologically advanced economy. Because of the increases in demand brought about by an increasing population and an increased standard of living, more fuel is needed. Due to the millions of years it takes for fossil fuels to form, we cannot replace them. Fossil fuels will one day run so low that it will no longer be economically viable to locate, recover, and refine them. The need to develop alternative energy sources is important for this reason.

Coal

The forming of coal in the earth began about 500 million years ago. It took approximately 85 million years for plant and animal decay to form into coal. Coal can be a soft or rocklike material. It is black or brown, depending on its age. The older the coal is, the denser it is, and the blacker it becomes. Coal is combustible and frequently used to generate electricity by power companies, to generate heat for industrial processes, and to heat some homes and buildings. See **Figure 3-2.**

Figure 3-2. A large number of electrical generating plants burn coal to generate steam that drives the turbines.

Removing coal from the ground is called *mining*. Coal, once mined, can be burned immediately as a fuel. There are two mining methods: deep mining and surface mining. ***Deep mining*** uses shafts and special machinery to remove the coal from deep below the earth's surface. See **Figure 3-3.** This type of mining can be dangerous due to cave-ins and machinery accidents.

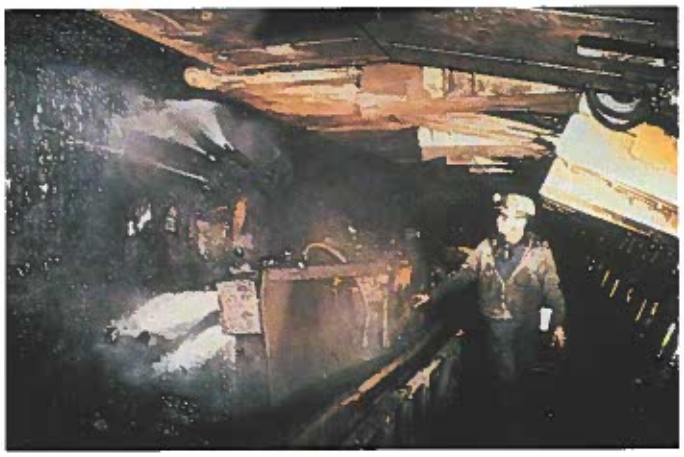


Figure 3-3. Deep mining involves following coal seams deep underground, breaking up the coal into manageable-sized pieces, and bringing it to the surface. The operation is highly mechanized, but mining continues to be one of the most dangerous occupations. (American Coal Foundation)

Deep mining: A mining operation that uses shafts and special machinery to remove the coal from deep below the earth's surface.

Surface mining, or ***strip mining***, is the mining or removing of coal close to the earth's surface. It is done mainly with the use of large pieces of machinery, such as mechanical shovels and bulldozers. See **Figure 3-4.** Surface mining is much safer and less expensive than deep mining.

The one major disadvantage to surface mining is the condition it leaves the land in after the coal has been gathered. In some instances, mining companies are required to restore the land to usable condition after strip mining has taken place. This restoration is referred to as ***land reclamation***. Strip mining is the preferred method of retrieving coal as long as the coal seam is less than 60' deep. When strip mining, the topsoil is removed and stored in piles for later use during reclamation. Next, the remaining soil is removed down to the top of the coal seam. This remaining soil is referred to as the ***overburden***.

Strip mining: The mining or removing of coal close to the earth's surface. It is done mainly with the use of large pieces of machinery, such as mechanical shovels and bulldozers. Also called *surface mining*.

Land reclamation: The restoration of land to a usable condition after strip mining has taken place.

Overburden: When strip mining, the soil remaining after the topsoil is removed.

Once mined, the coal is typically transported by rail, but it can also be transported by barge or truck to power plants and other destinations for end use. See **Figure 3-5.** The coal at power plants is typically stored in a huge pile, since power plants are required to have a 60-day supply of coal on hand. The 60-day supply is necessary in case of labor strikes or natural disasters that could prevent coal shipments for a period of time. At the power plant, the coal is fed into mills that grind it into a fine powder. In this way, the coal produces the greatest amount of energy and the least

Figure 3-4. Coal located near the surface of the earth is mined by stripping away the dirt and rock above the coal seam. The exposed coal can then be broken up and shipped to electrical generating plants or other end users. Very large equipment, such as this shovel and truck, is used to mine with maximum efficiency. (P&H Mining Equipment)

Figure 3-5. Coal is typically shipped from mines to end users by railcar or on large barges, such as this one. Coal-fired electrical generating plants are often located along waterways to take advantage of lower-cost barge shipment.

Peat: The first step in the formation of coal. It is formed from water and the decomposition of organic materials.

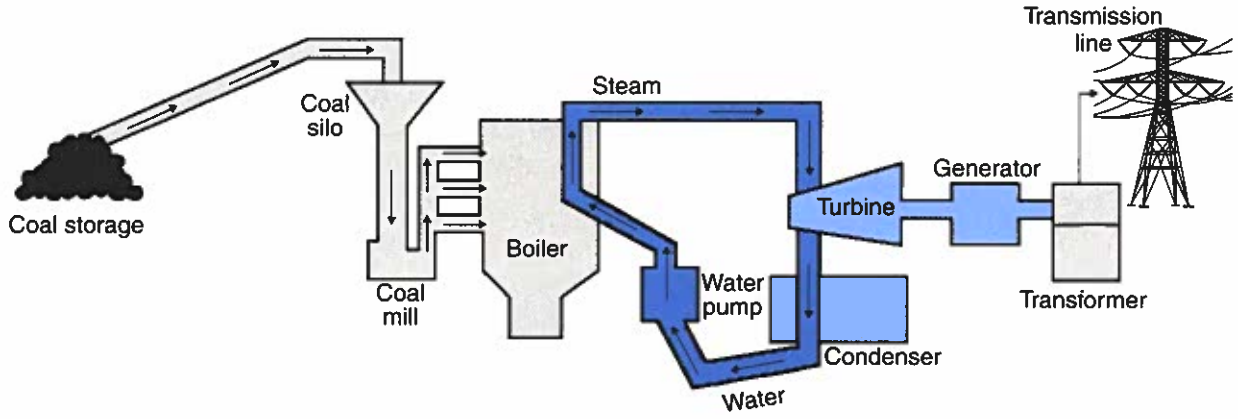
amount of waste when injected into the boiler. In the boiler, the burning coal is used to heat water into steam. The steam drives a turbine. The turbine spins a generator, which produces the electricity. The electricity is then transformed into very high-voltage electricity, which is suitable for long-distance distribution. It is sent through transmission lines to various communities. See **Figure 3-6.**

Types of coal

Peat is a step in the formation of coal more than a type of coal. It is formed from water and the decomposition of organic materials. When dried, this material can be used as a fuel source for home heating. Some pellet stoves and coal stoves are designed for use with peat. Since peat takes so much less time to form than coal, it is actually considered to be a renewable form of energy. It is simply mentioned here as the first step in the formation of coal.

Lignite coal is the next youngest type of coal. This material contains some woody decomposition that can be recognized as peat, but it has a higher energy content than peat. It too contains a large amount of moisture and is brownish in color, as opposed to the black substance typically recognized as coal. Lignite has enough energy content per volume that it can be used for the production of electricity or as an industrial fuel.

Figure 3-6. A schematic of a large coal-fired electric generating plant.



Subbituminous coal is estimated to be at least 200 million years old. It contains greater energy content per volume than lignite and is frequently used as an industrial fuel, for space heating, and for the generation of electricity. This coal is dull black in color and is categorized as a "soft" coal, a name used to describe the physical characteristics of peat, lignite, and subbituminous coals.

Bituminous coal has a high carbon content. It is denser and blacker than most other forms of coal. This type of coal is principally used for the production of electricity.

Anthracite coal is hard and brittle. It appears shiny on the surface and has a high carbon content. Because it burns cleaner than other forms of coal, it is often used for home heating. It does not have as much energy content per volume as bituminous coal. **Figure 3-7** shows the various types of coal and compares their carbon content and energy potential.

Lignite coal: A type of coal containing some woody decomposition that can be recognized as peat, but it has a higher energy content than peat. It contains a large amount of moisture and is brownish in color, as opposed to the black substance typically recognized as coal.

Subbituminous coal: Coal that contains greater energy content per volume than lignite and is frequently used as an industrial fuel, for space heating, and for the generation of electricity. This coal is dull black in color and is categorized as a "soft" coal.

Bituminous coal: Coal with a high carbon content. It is denser and blacker than most other forms of coal. This type of coal is principally used for the production of electricity.

Anthracite coal: Coal that is hard and brittle. It appears shiny on the surface and has a high carbon content. Because it burns cleaner than other forms of coal, it is often used for home heating. It does not have as much energy content per volume as bituminous coal.

Figure 3-7. There are several different types of coal. They differ in carbon percentage and energy content.

Types of Coal		
Rank	**Carbon (%)**	**Energy Content (Btu/lb)**
Peat	< 30	1000–4000
Lignite	30	5000–7000
Subbituminous	40	8000–10,000
Bituminous	50–70	11,000–15,000
Anthracite	90	14,000

Supply and demand for coal

World coal reserves are concentrated in the United States, the former Soviet Union, and China. Coal is used extensively for the production of electricity throughout the world. The use of anthracite coal primarily for home heating is expected to decline in future decades. Coal is a difficult and labor-intensive fuel, compared to oil and natural gas.

The worldwide demand for coal has been in a period of slow growth since the late 1980s. This trend is expected to continue, with growth of worldwide coal consumption estimated at about 1.5% per year. More than half of all coal consumed worldwide is for power generation. Virtually all projected growth for the use of coal is for power generation, since other fuels are cleaner to heat with and easier to distribute in small quantities.

Coal can also be converted to a synthetic gas or liquefied fuel. These fuels are typically referred to as *synfuels*. They could be used to supplement oil and natural gas supplies, if these supplies become scarce.

Coal and the environment

Strip mining can be devastating to the land. Fortunately, reclamation techniques often convert a strip-mined plot to an area suitable for farming, once strip mining has been completed. See **Figure 3-8.**

Figure 3-8. Reclamation efforts by coal-mining companies are designed to restore strip-mined land to farming or other uses. A—Crops planted on restored land at a former strip mine in Ohio. B—Large-scale reforestation is becoming widely practiced. This project is at a former mine in the state of Washington. C—Mining land can be reclaimed for recreational use, such as this golf course in Pennsylvania. (Chuck Meyers, Office of Surface Mining, Department of the Interior)

Bag filter: A device that works like a bag on a vacuum cleaner, trapping all solid particles in the waste stream prior to the hot waste gases exiting through the smokestack of a power plant.

Electrostatic precipitator: A device that works by positively charging waste particles and attracting them to a negatively charged electrode. The solid particles are then washed off the electrode and collected.

Fly ash: A solid waste by-product produced by burning coal.

Petroleum: Oil.

Crude oil: Oil in its natural state.

Burning coal can be a dirty process. This is particularly true when the coal is burned in small quantities, such as in a coal stove in a residential setting. When large amounts of coal are consumed in one area, the process can be much more effectively monitored and treated, from an environmental standpoint. Pollution control techniques have improved drastically in recent decades. Devices such as bag filters and electrostatic precipitators filter solid particles out of the exhaust gases before they are discharged into the atmosphere.

A ***bag filter*** works essentially the same way as a bag on a vacuum cleaner. All solid particles in the waste stream are trapped in the bag filter prior to the hot waste gases exiting through the smokestack of the power plant. An ***electrostatic precipitator*** works by positively charging the waste particles and attracting them to a negatively charged electrode. The solid particles are then washed off the electrode and collected. This solid waste by-product, known as ***fly ash***, historically had no use. It was stored in fly ash pools, which were large holes often dug near the power plant. More recently, fly ash has been used as traction grit in the northern states, where the roads become covered by snow and ice. It can also be used as an additive in concrete and as an absorbent material for oil spills.

Oil

Oil is also known as ***petroleum***. Like coal, petroleum is a fossil fuel. In its natural state, petroleum is called ***crude oil***. As crude oil comes from the ground, it is a mixture of semisolids, liquids, and gases. Oil has many uses. The biggest users of oil are transportation systems. Some form of oil fuels almost all transportation vehicles. Like coal, oil is found underground. To get oil out of the ground, an operation known as drilling is necessary. See **Figure 3-9.**

Before drilling for oil, there are several tests that need to be done on the surface and underlying rock. Certain drill bits are selected, depending on the method used to drill. Large drill bits are used to cut through layers of the earth. Drilling can occur as far as 3–5 miles below the earth's surface.

Figure 3-9. Oil is extracted from formations beneath the land and oceans by drilling into the formations and pumping the oil to the surface for transport by ship or pipeline. This is a large floating platform anchored over a well in England's North Sea oil field. (Kerr-McGee Corporation)

GREEN TECH

Obtaining oil can sometimes result in oil spills. These spills not only result in wasted energy sources, but they also adversely affect the animals and environment.

Career Connection

Petroleum Engineers

Science, Technology, Engineering & Mathematics

Petroleum is an exhaustible energy resource, and it is considered to be nonrenewable because it will take millions of years to replenish our supply once we have used it all. It must be drilled and refined in order to be useful. Petroleum engineers are responsible for overseeing the process of gathering and testing the oil.

The work of petroleum engineers entails designing the equipment used to drill and refine the oil. The tasks of these engineers also include researching to find the best locations for oil wells. Once the oil is drilled, petroleum engineers sample it and test its quality. They also work on making the process as efficient as possible while staying within environmental safety limits.

A petroleum engineer must be skilled in math and physics and possess an understanding of the properties of oil. In addition, leadership skills are also necessary to guide workers through the oil-refining process. To be a qualified petroleum engineer, a bachelor's degree is required. The yearly salary may range from $80,000 to $141,000.

Once the bit has struck an oil pocket, natural pressures cause the oil to rise to the earth's surface. Valves then control the oil. Pumps are also used to bring oil to the surface.

Once the oil is brought to the surface, it is transported by pipeline to a refinery. See **Figure 3-10.** A refinery is a place that turns crude oil into products such as gasoline, diesel fuel, kerosene, and lubricating oil. In a large tower, called a ***fractionating tower***, crude oil is separated into various

Fractionating tower: A large tower in which crude oil is separated into various products.

Figure 3-10. Refineries break down crude oil into gasoline, diesel fuel, heating oil, and other petroleum products.

products. The crude oil travels through a pipe into a furnace at the bottom of the tower. The furnace heats the crude oil until it boils. The vapors rise in the tower, and the temperature in the tower varies with the elevation. Some "fractions" condense at higher temperatures, while some condense at lower temperatures. Trays at the various levels collect the condensed fractions and drain them out of pipes. See **Figure 3-11.** The different products are then transported by way of pipeline to storage tanks or another refinery.

Oil shale: 40–50 million-year-old sedimentary rock containing an oily substance.

Kerogen: An oily substance contained by 40–50 million-year-old sedimentary rock.

Oil shale and tar sands

In a region known as the Green River formation, where Utah, Wyoming, and Colorado join, there exists more shale oil than there are proven crude oil reserves in the United States. Recovering the oil is not easy. Like other oils, shale oil is the result of decaying vegetation that is millions of years old. ***Oil shale*** is a 40–50 million-year-old sedimentary rock containing an oily substance. This substance is called ***kerogen***. The oil is trapped in the rock and is generally crushed and heated to a minimum

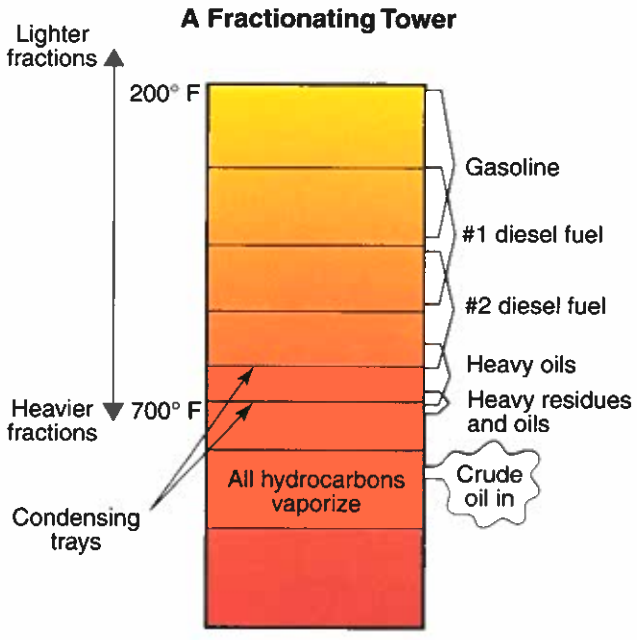


Figure 3-11. The fractionating tower is at the heart of the refining process. The oil is heated, causing all the hydrocarbon compounds to vaporize. Different "fractions" of the oil vapors, such as gasoline or diesel oil, condense out as they rise in the column.

of 800°F, so it can become liquefied for separation. This process is known in the industry as *retorting*. The yield from oil shale is only about 30 gallons of oil for every ton of rock that is excavated and crushed. Additionally, the conventional refining process requires large amounts of water in an area of the country where water is not plentiful. Shale oil is known to be present, but the economics of recovery are not yet favorable, as was proven by several attempts in the 1980s to develop pilot sites in the Green River formation.

STEM Connection

Technology: The In Situ Process

One experimental retorting process, known as the *in situ* (meaning "in place") process, may have some potential. This process calls for extraction of oil, while leaving the rock in place. See **Figure 3-A.** Imagine a tunnel that runs down one shaft, across the bottom of a plot of land known to be rich in shale oil, and then up another shaft on the other side. In the two vertical ends of the shaft, electrodes used to microwave the ground in between are inserted. The horizontal shaft below serves as a collection point, where heated oil is pumped to the surface. Other more conventional means of generating heat in the rock, such as injecting steam, are also used to retort the shale oil from the rock without removing the rock.

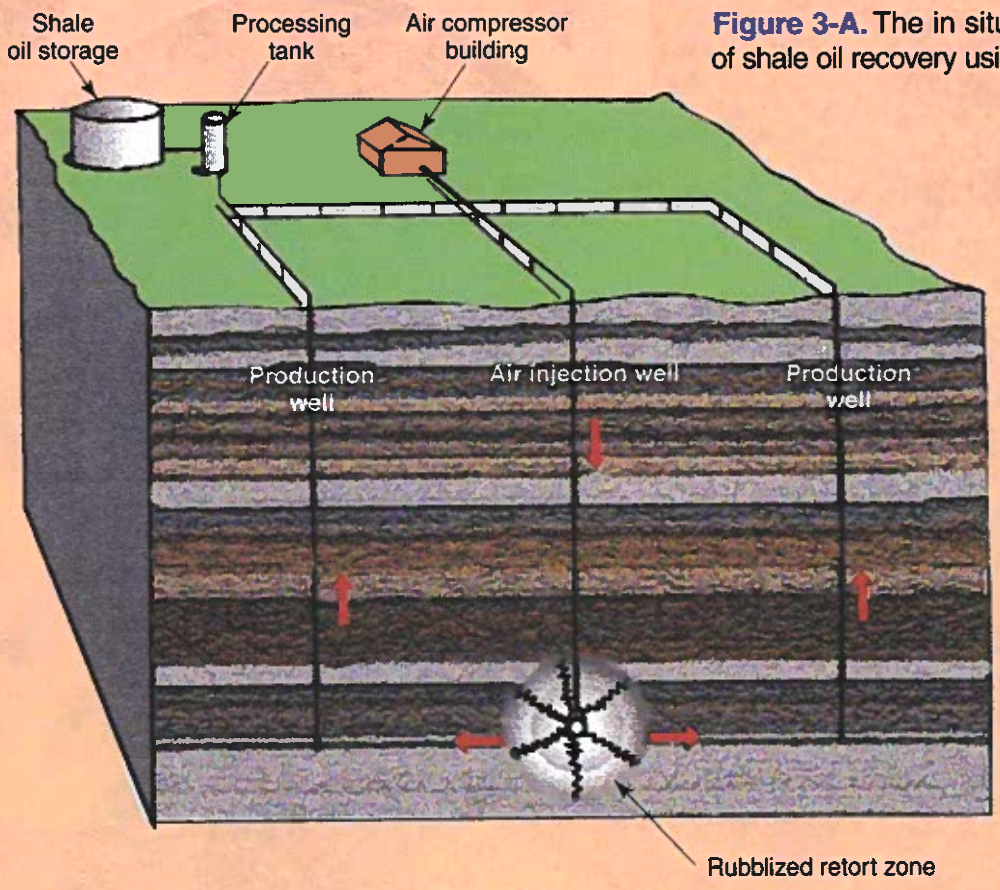


Figure 3-A. The in situ process of shale oil recovery using steam.

Tar sand: A source of crude oil. The sand is mined and mixed with hot water or steam to extract the thick oil known as bitumen.

Another important source of crude oil for the future may lie in ***tar sands***. These tar sands are similar to oil shale in that the oil cannot be retrieved through conventional means, such as well drilling. The largest reserves of tar sands in the world are located in Alberta, Canada. Again, extracting the oil from the sand is not easy. At present, the sands are mined and mixed with hot water or steam to extract the thick oil known as *bitumen*. The United States has some limited proven reserves of tar sands.

Supply and demand for oil

GREEN TECH
In an effort to reduce our dependence on oil, hybrid vehicles and different types of fuel, such as E85, are now in wide use in the U.S.

Over the past 25 years, oil prices have been the most volatile of all fossil fuels. This is due in large part to the instability of the Middle East, where much of the oil is produced, and the fact that a significant percentage of the oil used in the United States and elsewhere is imported. Since the United States imports large quantities of oil, the United States is subject to the discretions of other countries with regard to oil more than any other energy source.

The United States is vulnerable when it comes to imported oil. Oil prices have been significantly affected by labor strikes, wars, and the desire of the Organization of Petroleum Exporting Countries (OPEC) leaders to reduce production in order to keep the price of imported oil high. Limits to long-term oil price escalation may be on the horizon, however. They include the introduction of new fuels as a gasoline substitute, increased fuel efficiency leading to greater fuel economy, and new non-OPEC world markets for oil production, particularly in the former Soviet Union, where many deep water reserves of oil have recently been discovered. Projections for domestic oil consumption indicate it will continue to rise at a rate faster than any other fuel, with the exception of natural gas. This is due, in large part, to the fact that the United States uses oil so extensively as a fuel in the various transportation industries. See **Figure 3-12.**

Oil and the environment

Oil is a relatively safe fuel to transport and work with, even when it is refined into gasoline. For all the oil consumed on a daily basis, relatively

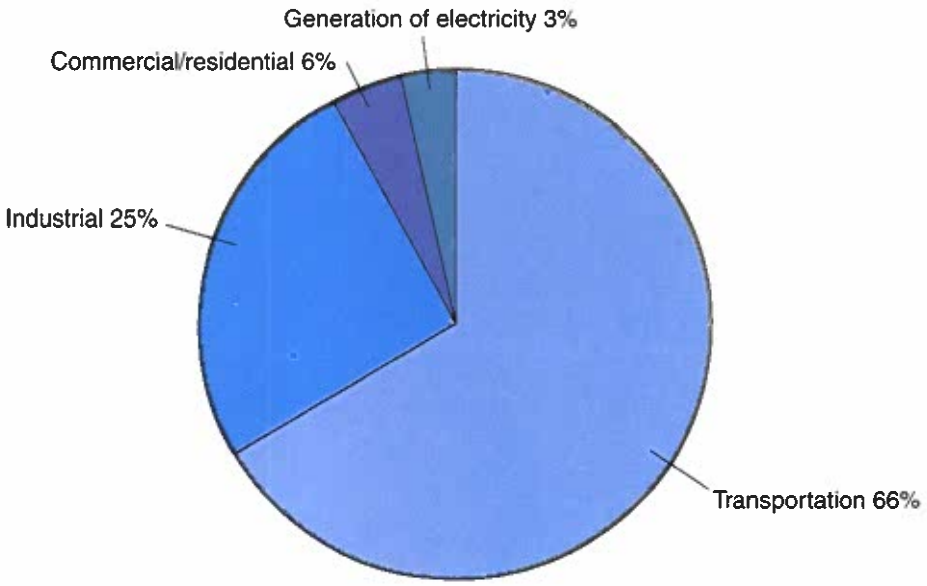


Figure 3-12. U.S. oil consumption. Two-thirds of all oil is typically consumed by the transportation sector, reflecting the nation's heavy dependence on vehicles powered by internal combustion engines. (U.S. Energy Information Administration)

Technology Link

Construction: The Trans-Alaska Pipeline

In 1968, the largest oil reserve on American soil was discovered on the North Slope of Alaska. This reserve is estimated to contain about 10–20 billion barrels of oil. An 800-mile long, 48" diameter pipeline was completed in 1977 to carry oil from the North Slope to the Gulf of Alaska, where it can be shipped to refineries. See **Figure 3-B.** Construction of the pipeline cost more than $8 billion. This was the largest privately funded construction project of its time. Construction took more than three years and crossed over three mountain ranges. Thirty-one lives were lost while constructing the pipeline. The estimated 1.2 million barrels of oil per day that flow through the Trans-Alaska Pipeline represent approximately 20% of all domestic oil production in the United States. More recently, another huge oil reserve has been detected in the Arctic National Wildlife Refuge (ANWR). Drilling within the refuge would allow oil companies to make use of the already existing Trans-Alaska Pipeline to transport oil down to the shipping terminal, but there is opposition to the plan from many environmentalists. The refuge was created to protect the land from development, and it is home to many animals and birds. On the other hand, continued reliance on foreign oil and the increased cost of oil are reasons proponents argue in favor of opening up at least a small part of the refuge for drilling and continued exploration.

Figure 3-B. The Trans-Alaska Pipeline stretches 800 miles from the North Slope to the Gulf of Alaska.

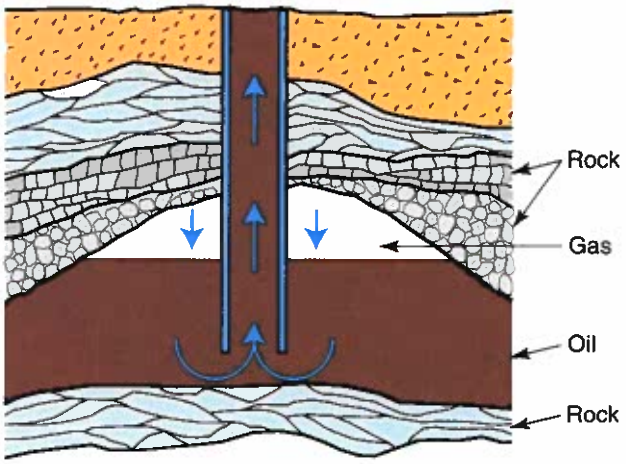
few accidents occur with the fuel. It is possible for a fuel tank to explode if it is punctured in a certain way, but this is not common. Yet, oil is a fossil fuel, and like all fossil fuels, it has environmental drawbacks. Consumption of oil results in the production of carbon dioxide (CO_2),

carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur oxides (SO_x). Nitrogen oxides are major contributors to smog and respiratory problems. Sulfur oxides are other contributors to smog and the principal contributors to acid rain, which is harmful to the ecology of lakes and streams. Another environmental concern about oil is how it is transported. Since so much oil is imported worldwide, shipping of oil is common. Occasionally, mishaps occur that create environmental disasters, such as the *Exxon Valdez* accident in 1989.

Natural Gas

The gaseous portion of petroleum is called *natural gas*. Natural gas is always found wherever oil deposits are discovered. See **Figure 3-13.** This gas comprises ethane, propane, methane, and butane. These are all combustible gases. Natural gas is primarily composed of methane. Of the gases found within natural gas, butane offers the greatest British thermal unit (Btu) content per volume. Natural gas is the cleanest burning and presently the least expensive of the fossil fuels, and it has become one of the major sources of energy because of these characteristics.

Figure 3-13. Natural gas is always found above crude oil deposits.



Removing gas from the ground is done in much the same way as recovering oil. Wells are drilled into the ground. The gas is removed and transported by way of pipeline to a processing plant. At the plant, all the impurities, like dirt, moisture, and sulfur, are removed. The gas is then transported to homes and industrial establishments for use.

Gas can be easily transported through pipelines in its natural state, helping to keep the cost of transporting the fuel to populated areas quite low. It is usually stored underground. During the warm months, when not much gas is needed for heating purposes, the gas from the pipelines is stored in underground reservoirs. These reservoirs are called ***aquifers***. An aquifer is a rock formation underground. These reservoirs hold large quantities of water. When the gas is pumped in under pressure, it pushes the water down farther into the ground. See **Figure 3-14.**

Aquifer: An underground rock formation that acts as a reservoir for large quantities of water. It is used to store gas from pipelines.

Liquefied natural gas (LNG): Gas that has been placed under pressure at very low temperatures, allowing transportation by railroad tankers, truck tankers, and ships.

The transporting of gas in pipelines to more rural areas can get rather expensive. Building pipelines to transport gas everywhere is difficult. To solve these problems, gas has been placed under pressure at very low temperatures to create ***liquefied natural gas (LNG)***. LNG provides a safe and viable alternative to gas in its natural state for many rural communities in which installing natural gas lines would not be economically possible. It can be delivered by truck and stored in tanks on-site at rural farms, businesses, and homes. See **Figure 3-15.** With liquefied gas, transportation can also occur by using railroad tankers and ships. Much more liquefied gas can be stored in a holding tank than gas in its natural state. When

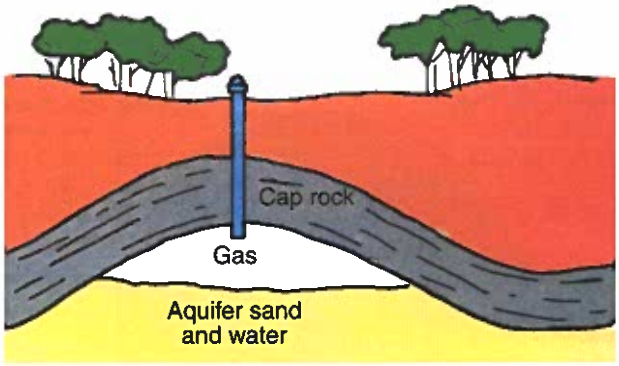
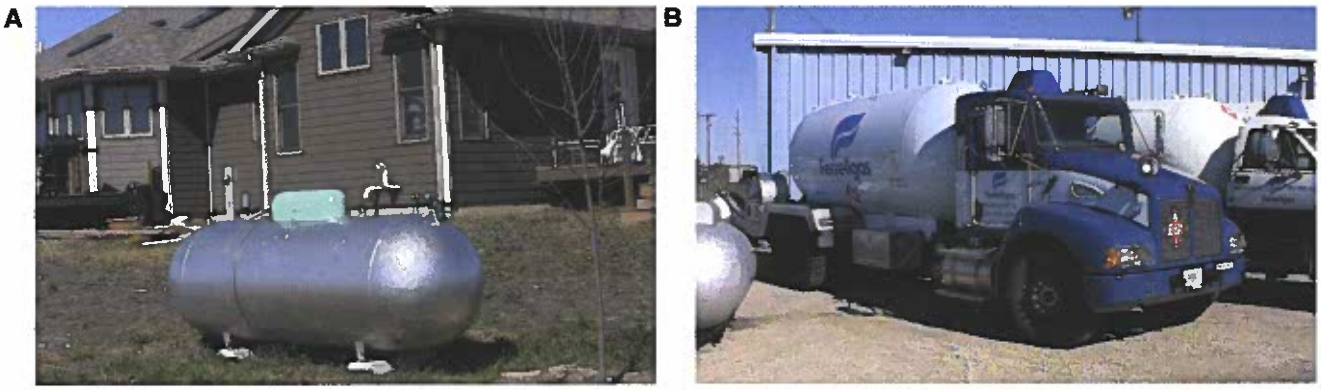


Figure 3-14. Natural underground aquifer formations covered with an impervious cap rock layer can be used for storage. The gas is pumped into the formation under pressure, displacing the water.

Figure 3-15. Homes in rural areas away from pipelines and distribution systems rely on liquefied natural gas (LNG) stored in tanks. A—A storage tank outside a home. B—A specially designed small tanker truck used to fill storage tanks at customers' homes or businesses.



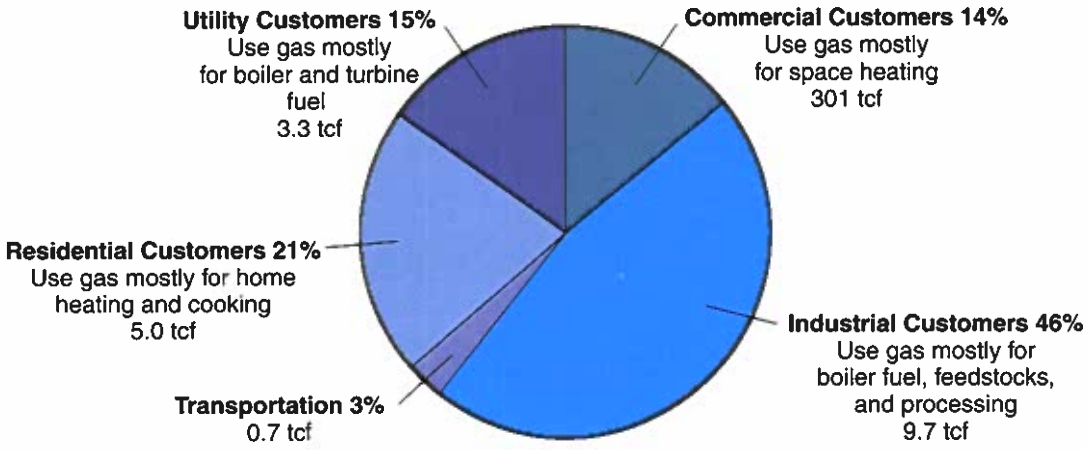
purchasing gas, it is sold by the cubic foot (ft^3). A ***therm*** is equivalent to 100 ft^3 of natural gas and is typically used instead of the ft^3, since the ft^3 is such a small quantity. The therm is abbreviated as ccf, representing 100 ft^3.

Therm: The equivalent of 100 cf (cubic feet) of natural gas.

Supply and demand for natural gas

Natural gas is expected to be the fastest-growing component of world energy consumption over the next 25 years. The developing nations are anticipated to require the most growth in natural gas energy consumption. In the United States, natural gas is used extensively in the industrial, commercial, and residential sectors of our economy. It is an ideal fuel for structural heating, cooking, and many industrial processes. One sector of our economy that natural gas is not used for extensively at this time is the transportation sector. See **Figure 3-16.** Efforts are also underway to replace more polluting energy sources with natural gas in major urban areas, such as Beijing and Shanghai, China. Natural gas reserves have improved since the 1970s, but like most energy resources, the distribution is not evenly spread throughout the world. Over 70% of the current proven reserves are located in the Middle East and the former Soviet Union nations. Russia and Iran alone account for almost half of the world's proven reserves of natural gas.

Figure 3-16. U.S. natural gas consumption by end-use sector. (U.S. Energy Information Administration)



GREEN TECH
An alternative energy source that may be used residentially uses solar panels. Another potential alternative energy source may be fuel cells.

Natural gas and the environment

Natural gas is the cleanest burning of all the fossil fuels. It may also be the most dangerous of all the fossil fuels. When a natural gas leak occurs within a home, the carbon in the fuel mixes into the bloodstream and works to put people and animals into a deep sleep. This is known as carbon monoxide poisoning.

Acid Rain and the Greenhouse Effect

Two of the environmental problems most closely associated with the burning of fossil fuels are the creation of acid rain and greenhouse effect gases. *Acid rain* is a broad term often used to describe the primary ways acid comes back to the ground from our atmosphere. A more accurate term used among those in the field is *acid deposition*. Wet deposition is related to acidic rain, fog, and snow. Sulfur dioxide (SO_2) and nitrogen oxides created by the burning of fossil fuels linger in the atmosphere until mixing with rain, fog, or snow and returning to earth. As the acidic water flows over and through the ground, it affects plants and animals in many ways. The types of vegetation and the buffering capacity of the soil to filter out the acid all factor into how much damage acid rain can cause. Fish in ponds suffering from acid rain are particularly susceptible. About half of all acid rain is created from dry deposition, or gases and particles, that falls back to earth on trees and structures until washed off by the next rainfall. This can create a particularly concentrated dose of acid rain. Winds can also blow the dry deposition to other places.

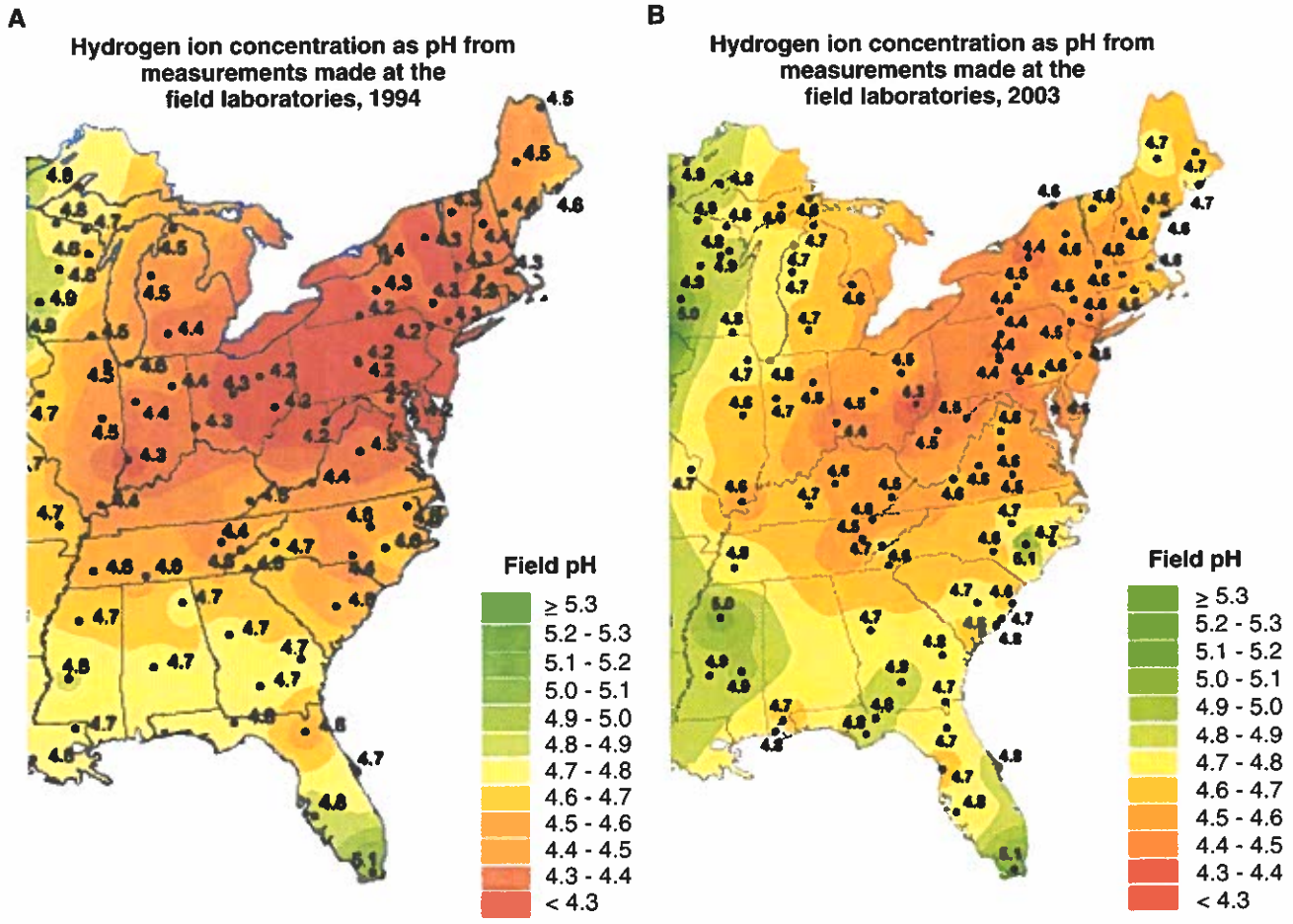
The primary culprit in the production of acid rain is the electric utility industry. Scientists have confirmed that over 65% of all sulfur dioxide and about 25% of all nitrogen oxides in the environment are results of burning coal and other fossil fuels for electric power generation. The sulfur dioxide and nitrogen oxides react with water, oxygen, and other chemicals in the atmosphere to form acidic compounds. Sunlight increases the rate at which these chemical reactions occur, and the result is mild sulfuric acid and nitric acid that can be damaging to entire ecological systems and even

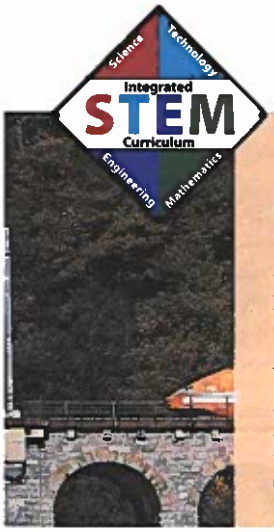
buildings. Acid rain is monitored using the pH scale for measuring acidity. See **Figure 3-17.** The lower the pH of a substance, the more acidic it is. Pure water has a pH of 7.0, but normal rain is slightly more acidic from absorbing CO_2 as it falls to earth. The most acidic rain on record in the United States had a pH of approximately 4.3. Some other countries with government-owned electrical generating facilities are much worse. These plants are often constructed with far less environmental pollution control devices than those required in the United States. The ***Environmental Protection Agency (EPA)*** supports the monitoring of acid rain in this country.

Environmental Protection Agency (EPA): An organization that supports the monitoring of acid rain in the United States.

The *greenhouse effect* is a term used to describe the gradual warming of the earth's lower atmosphere. Some elements of the greenhouse effect occur naturally and have occurred long before human inhabitance of the earth. The greenhouse effect is important because, without it, the planet would not be warm enough for humans to live. Certainly, forest fires, volcanoes, and other naturally occurring events have been pumping gases from combustion into the atmosphere since the formation of the earth.

Figure 3-17. Efforts to clean up emissions from fossil fuel–burning power plants and other sources contributing to acid rain have been effective. The lower the number and the more orange the color, the more acidic the reading. A—The situation in 1994 shows very high acidity in large areas of the United States. B—In 2003, the readings were generally lower in all areas. (National Oceanic and Atmospheric Administration)





STEM Connection

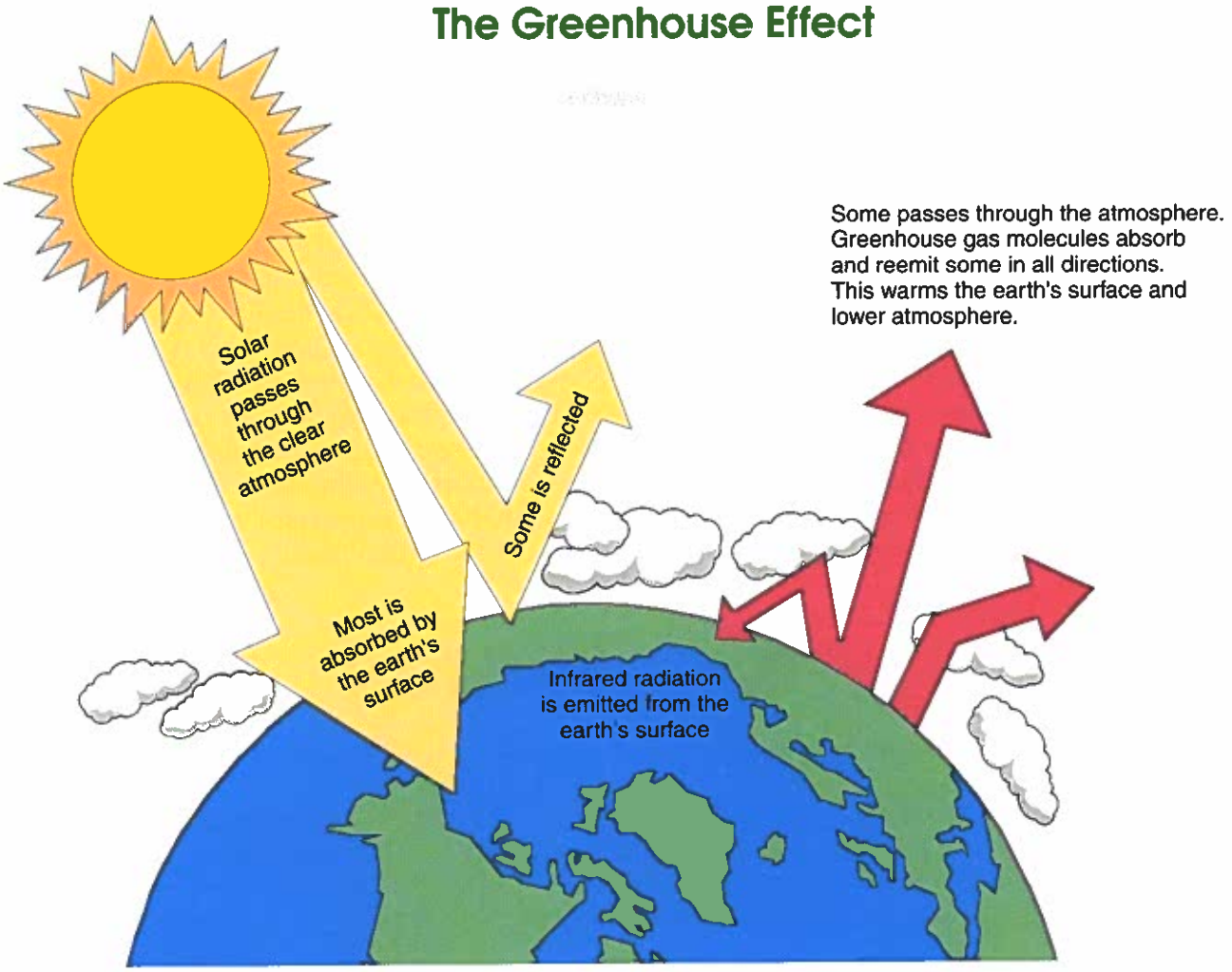
Science: The Greenhouse Effect's Impact on the Polar Ice Cap

With the rise in average global temperatures, the polar ice cap is slowly melting. The polar ice cap reflects sunlight back into space, rather than allowing the earth to absorb the heat. This process is called *albedo*, and it helps maintain the earth's temperature.

As the polar ice cap melts and is reduced in size, it cannot reflect as much sunlight back into space. This causes more heat to be retained by the earth's surface. This adds to the gases and particles involved in the greenhouse effect and global warming. The problem seems to be an unchangeable cycle, but scientists continually research the ways we can slow or halt the progression of global warming.

There is growing evidence, however, that since the mid-1800s, when the use of fossil fuels started to become widespread, there has been a marked increase in greenhouse gases. The greenhouse effect occurs naturally. As sunlight strikes the earth's surface, some of it is reflected back toward the atmosphere. Some light is also converted to heat used to warm the land and seas of the planet. Ultimately, this heat is also given up to the atmosphere, as these bodies cool. Greenhouse gases in the atmosphere serve to blanket the planet, holding the heat in our near atmosphere. See **Figure 3-18.** The concern is that, through the consumption of fossil fuels, we are creating too many greenhouse gases, including carbon, hydrogen, and even oxygen. These gases, which can form as water vapor, CO_2, methane, and ozone greenhouse particles, such as dust and soot, are helping to hold too much heat in the earth's atmosphere. The earth's average temperature is known to have increased by almost 1°F since the late 1800s. The cause of this increase has not yet been proven. There is likely a relationship, however, between CO_2 levels in the atmosphere and the continued consumption of fossil fuels. Continuing fossil fuel consumption at present rates could lead to a global warming effect that could alter weather and vegetation patterns throughout much of the earth. Other potential consequences of global warming could be the melting of icebergs and polar ice enough to literally change coastlines. Some estimates predict that permanent damage from global warming may begin to appear in the near future.

Figure 3-18. The greenhouse effect holds in heat, creating global warming, which can cause serious environmental damage to the planet.



Career Skills

Résumés

A résumé is a brief outline of your education, work experience, and other qualifications for work. A well-written résumé can help you get an interview.

A list of references should accompany your résumé. A reference is an individual who will provide important information about you to a prospective employer. A reference can be a teacher, school official, previous employer, or any other adult outside your family who knows you well.

You can have your references write letters of recommendation for you. These give an employer a more in-depth look at your skills. Make sure you choose references who are good writers, since they will be representing you.

Summary

Fossil fuels are responsible for about 90% of all energy production worldwide. They were formed over millions of years, as organic material decomposed. The consumption of these nonrenewable sources of energy creates environmental consequences, such as greenhouse effect gases and acid rain. Additional environmental hazards include the threat of oil spills, such as the *Exxon Valdez* oil spill, which occurred in 1989. Some fossil fuels, such as oil, must be imported from other countries, which can lead to economic and political consequences. Other fossil fuels, such as coal, are plentiful in the United States and can be converted to gas or liquefied petroleum products. This is unlikely to happen unless prices of conventional fuels rise dramatically. Fossil fuels such as tar sands and shale oil contain much energy that, to date, has largely gone untapped. This is because of the difficulty in retrieving these resources. Despite all the misgivings about the use of fossil fuels, these fuels are highly likely to remain the major sources of energy worldwide for several decades, until some combination of economics, technology, politics, and environmental concerns usher in sources to replace them.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

anthracite coal
aquifer
bag filter
bituminous coal
crude oil
deep mining
electrostatic precipitator
Environmental Protection Agency (EPA)
fly ash
fractionating tower
kerogen
land reclamation
lignite coal
liquefied natural gas (LNG)
natural gas
oil shale
overburden
peat
petroleum
strip mining
subbituminous coal
tar sand
therm

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. *True or False?* Fossil fuels are responsible for about 30% of all energy consumed in the United States.
2. *True or False?* The primary use for oil in the United States is for home heating.
3. Explain why the use of fossil fuels remains so prevalent today.
4. *True or False?* Natural gas is often found where oil is found.
5. *True or False?* Coal is primarily used in the production of electricity.

6. *True or False?* The United States is fortunate to have massive coal reserves.
7. The two methods of mining are known as _____ and _____ mining.
8. Summarize the major components of a coal-fired generating plant.

Matching questions: For Questions 9 through 13, match the phrases on the left with the correct term on the right.

9. _____ Formed from water and the decomposition of organic materials.
10. _____ Very moist and brownish in color.
11. _____ Dull black and "soft."
12. _____ Very dense and black, with a high carbon content.
13. _____ Shiny, brittle, and often used for heating homes.

A. Anthracite.
B. Bituminous.
C. Lignite.
D. Peat.
E. Subbituminous.

14. Write a brief justification for the use of coal liquefaction.
15. Means of limiting emissions from a coal-fired power plant include _____ and _____.
16. A(n) _____ tower is used to distill crude oil into various products.
17. What is the relationship between the United States and the Organization of Petroleum Exporting Countries (OPEC)?
18. Discuss both the positive and negative impacts of importing oil.
19. *True or False?* Tar sands and shale oil are major contributors to the world energy production, at present.
20. _____ has the greatest British thermal unit (Btu) content of all the hydrocarbons that comprise natural gas.
21. Natural gas is transported primarily by:
    A. tanker ship.
    B. rail.
    C. pipeline.
    D. truck.
22. *True or False?* Natural gas is measured by the ccf or therm.
23. Which of the following fossil fuels is most abundant in the United States?
    A. Coal.
    B. Oil.
    C. Natural gas.
    D. Tar sands.
24. List and describe at least four concerns about the use of fossil fuels.
25. *True or False?* The pH scale is often used to measure the energy content of coal.

26. Which of the following measurements would indicate the greatest acidity?
    A. 3.2.
    B. 4.6.
    C. 7.0.
    D. 8.3.

27. *True or False?* One positive outcome of the consumption of fossil fuels is that of global warming.

28. Problems associated with the consumption of fossil fuels include:
    A. acid rain.
    B. the greenhouse effect.
    C. global warming.
    D. All of the above.

STEM Activities

1. Visit a power plant powered by a fossil fuel.
2. Calculate how much energy of a given source would be required to heat a specific space.
3. Write a paper about environmental concerns associated with burning fossil fuels.