Chapter 14
Resource Issues

Key Issues

1. Why are resources being depleted?
2. Why are resources being polluted?
3. Why are resources being reused?
4. Why should resources be conserved?

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Geographers study the troubled relationship between human actions and the physical environment in which we live. A **resource** is a substance in the environment that is useful to people, is economically and technologically feasible to access, and is socially acceptable to use. Resources include food, water, soil, plants, animals, and minerals. The problem is that most resources are limited, and Earth has a tremendous number of consumers. Geographers observe two major misuses of resources:

1. We deplete scarce resources — especially petroleum, natural gas, and coal.
2. We destroy resources through the pollution of air, water, and soil.

Nowhere is the globalization trend more pronounced than in the study of resources. Global uniformity in cultural preferences means that people in different places value similar natural resources, although not everyone has the same access to them. In a global environment, all places are connected, so the misuse of a resource in one place affects the well-being of people everywhere.

Key Issue 1. Why Are Resources Being Depleted?

- **Energy resources**
- **Mineral resources**

Two kinds of natural resources are especially valuable to humans: minerals and energy resources. (441) MDCs want to preserve current standards of living, and LDCs are struggling to attain a better standard. All this demands tremendous energy resources, so as we deplete our current sources of energy, we must develop alternative ones.

Energy Resources

Historically, people relied on power supplied by themselves or by animals, known as **animate power**. **Biomass fuel**, such as wood, plant material, and animal waste, remains the most important source of fuel in some LDCs, but during the Industrial Revolution, MDCs converted to **inanimate power**, generated from machines.

Energy Supply and Demand

Around one-half of the world's energy is consumed in MDCs and one-half in LDCs, but MDCs contain around one-third the population of LDCs, so per capita consumption of energy is around three times higher in MDCs.

Three of Earth's substances provide five-sixths of the world's energy:

- **Coal.** Supplanted wood as the leading energy source in North America and Europe in the late 1800s.
- **Petroleum.** First pumped in 1859, not an important resource until the diffusion of motor vehicles.

- **Natural Gas.** Originally burned off as waste from oil drilling, now used to heat homes.

In MDCs, other energy comes primarily from nuclear and hydroelectric power. Burning wood and hydroelectric power provides much of the remaining energy in LDCs. Energy is used in three principal places:

1. **Businesses.** The main energy resource is coal, followed by natural gas and oil.
2. **Homes.** Energy is used primarily for heating of living space and water. Natural gas is the most common source, followed by petroleum (heating oil and kerosene).
3. **Transportation.** Almost all transportation systems operate on petroleum products. Only subways, streetcars, and some trains run on coal-generated electricity.

Petroleum, natural gas, and coal are known as **fossil fuels**. A fossil fuel is the residue of plants and animals that became buried millions of years ago. Two characteristics of fossil fuels cause great concern for the future:

1. **The supply of fossil fuels is finite.** Once the present supply is consumed, we must look to other resources for energy.
2. **Fossil fuels are distributed unevenly around the globe.** Some regions enjoy a generous supply, others have little.

Finiteness of Fossil Fuels

To understand Earth's resources, we distinguish between those that are renewable and those that are not:

- **Renewable energy** is replaced continually or at least within a human lifespan;
- **Nonrenewable energy** forms so slowly that it cannot be renewed.

The world faces an energy problem in part because we are rapidly depleting the remaining supply of the three fossil fuels, especially petroleum. We can use other resources for heat, fuel, and manufacturing, but they are likely to be more expensive and less convenient to use than fossil fuels.

Proven Reserves. How much of the fossil-fuel supply remains? Despite the critical importance of this question for the future, no one can answer it precisely. The amount of energy remaining in deposits that have been discovered is called a **proven reserve**. Proven reserves can be measured with reasonable accuracy. Proven reserves can be measured with reasonable accuracy — about 1.3 trillion barrels of petroleum, about 175 trillion cubic meters of natural gas, and about 1 quadrillion metric tons of coal.

At the current world petroleum consumption rate of about 31 billion barrels a year, Earth's proven petroleum reserves of 1.3 trillion barrels will last 43 years.

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At current rates, reserves of natural gas will last for about 49 years and coal would last 131 years.

Potential Reserves. The energy in undiscovered deposits that are thought to exist is a **potential reserve**. Potential reserves can be converted to proven reserves in several ways:

- **Undiscovered Fields.** The largest, most accessible deposits of fossil fuels already have been exploited. Newly discovered reserves generally are smaller and more remote.
- **Enhanced Recovery from Already Discovered Fields.** When it was first exploited,

petroleum. China changed from a net exporter to an importer during the 1990s.

OPEC. At first, Western companies set oil prices and paid Asian countries only a small percentage of their oil profits. Several LDCs possessing substantial petroleum reserves created the Organization of Petroleum Exporting Countries (OPEC) in 1960. OPEC's Arab members were angry at North American and Western European countries for supporting Israel during that nation's 1973 war with the Arab states of Egypt, Jordan, and Syria. So during the winter of 1973–1974, they flexed their new economic muscle with a boycott — Arab OPEC states refused to sell petroleum to the nations that had supported Israel. Soon gasoline supplies dwindled in MDCs. Each U.S. gasoline station received a small ration of fuel. European countries took more drastic action — the Netherlands, for example, banned all but emergency motor vehicle travel on Sundays.

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OPEC lifted the boycott in 1974 but raised petroleum prices from $3 per barrel to more than $35 by 1981. The rapid escalation in petroleum prices during the 1970s caused severe economic problems in MDCs, and manufacturers were forced out of business. The LDCs were hurt even more. They depended on low-cost petroleum imports to spur economic development, and their fertilizer costs shot up. North American and Western European states encouraged OPEC countries to invest in American and European real estate, banks, and other safe and profitable investments. Comparable investment opportunities were limited in less developed countries.

Changing Supply and Demand. The price of petroleum plummeted during the 1980s and settled during the 1990s at the lowest level in modern history, adjusting for inflation. Conservation measures dampened demand for petroleum in most developed countries. The average vehicle driven in the United States got 14 miles per gallon in 1975, compared to 22 miles per gallon in 2000. With petroleum prices remaining low, consumption increased; Americans bought more gas-guzzling trucks and sport-utility vehicles, and drove longer distances, and once again petroleum imports reached record levels. As in the 1970s, Americans were once again unprepared for the shock of steep oil price rises in the twenty-first century. Supplies were disrupted, yet global demand continues to increase, especially from LDCs led by China. At some point extracting the remaining petroleum reserves will prove so expensive and environmentally damaging that use of alternative energy sources will accelerate, and dependency on petroleum will diminish. The issues for the world are whether dwindling petroleum reserves are handled wisely and other energy sources are substituted peacefully. Given the massive growth in LDCs, MDCs may have little influence.

Mineral Resources

Earth has 92 natural elements, but about 99 percent of the crust is composed of 8 elements: oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. The eight most common elements combine with rare ones to form approximately 3,000 different minerals, all with their own properties of hardness, color, and density, as well as spatial distribution. Minerals are either metallic or nonmetallic. Each mineral potentially is a resource, if people find a use for it. When a new technological process or product is invented, demand can suddenly increase for a mineral that had little use in the past. Conversely, when a new process or product replaces an older one, demand may decline for a mineral important in the past. Mineral deposits are not uniformly distributed around the world. A handful of countries accounts for most of the world's supply of particular minerals. Further, the leading producers at this time are not always the countries with the most extensive reserves, an indication that the relative fortunes of states may change in the future.

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Nonmetallic Minerals

Building stones, including large stones, coarse gravel, and fine sand, account for 90 percent of nonmetallic mineral extraction. Nonmetallic minerals are also used for fertilizer. All four are abundant elements in nature with wide distributions. However, mining is highly clustered where the minerals are most easily and cheaply extracted.

• **Phosphorus:** One-fourth of the world's supply is mined in the United States; another one-third in Morocco and China. Morocco possesses one-half the world's reserves.

• **Potassium:** Obtained primarily from the evaporation of seawater. Principal sources include former Soviet Union countries, Canada, the U.S., and the Dead Sea, shared by Israel and Jordan.

• **Calcium:** High levels concentrated in the of the Western U.S. and Canada, as well as Russia's steppes.

• **Sulfur:** The United States and Canada are responsible for one-fourth of the world's production, with another one-fifth coming from China and Russia.

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Nitrogen, obtained from the atmosphere, is an even more important fertilizer. Capturing it from the atmosphere utilizes a lot of energy, so supply and demand is more associated with energy resources than other fertilizer elements. Another group of nonmetallic minerals — gemstones — are valued highly for their color and brilliance when cut and polished. Diamonds are especially useful in manufacturing. Two-thirds of the world's diamonds are currently mined in Australia, Botswana, and Russia.

Metallic Minerals: Ferrous

Metallic minerals have properties that are especially valuable for fashioning machinery, vehicles, and other essential components of an industrialized society. Many metals are also capable of combining with other metals to form alloys with yet other distinctive properties. Metals are known as ferrous or nonferrous. **Ferrous** metals include iron ore and other alloys used in the production of iron and steel. The term "ferrous" refers to the Latin word for iron.

Iron Ore. By far the world's most widely used ferrous metal is iron, which accounts for 5 percent of Earth's crust by weight and 95 percent of ferrous metal mineral extraction.

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Iron is prized for its many assets: a good conductor of heat and electricity, able to be attracted by a magnet and to be magnetized, and malleable into useful shapes. The critical importance of iron to the past four thousand years of human history is reflected by the application of the term "Iron Age" to the period. Mining of iron ore, from which iron is extracted, is concentrated in a handful of countries. Iron deposits of indifferent quality but close to market are actively mined, whereas large known deposits in remote areas are ignored for now, although they may become more important in the future once more accessible deposits are exhausted.

Other Ferrous Metals. Several less common ferrous metals are important for alloying with iron to produce steel: chromium, manganese, molybdenum, nickel, tin, titanium, magnesium, and tungsten.

Metallic Minerals: Nonferrous

Nonferrous metals are utilized to make products other than iron and steel. The most abundant nonferrous metal is aluminum.

Aluminum (Bauxite). Rarely used commercially prior to the twentieth century, aluminum is now in greater demand than any metal except iron. World reserves of aluminum are so large — more than 1,000 years at current rates of use — that it is essentially regarded as inexhaustible at realistic projections of future demand.

Other Nonferrous Metals. Other especially important nonferrous metals include copper, lead, and zinc. World supplies for some nonferrous metals are extremely limited — less than 60 years for copper, 25 years for lead, and 45 years for zinc.

Precious Metals. Nonferrous metals also include precious metals – silver, gold, and the platinum group. In addition to jewelry, both silver and gold are used in a variety of industrial applications, such as electrical and electronic products, and silver is a component of photographic film, whereas gold is important in dentistry.

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The principal use of the platinum group is in motor-vehicle catalytic converters to treat exhaust emissions, as well as fuel cells

Key Issue 2. Why Are Resources Being Polluted?

- **Air pollution**
- **Water pollution**
- **Land pollution**

In our consideration of resources, consumption is half of the equation — waste disposal is the other half. We rely on air, water, and land to remove and disperse our waste. Pollution occurs when more waste is added than a resource can accommodate.

Air Pollution
Air pollution is a concentration of trace substances at a greater level than occurs in average air. The most common air pollutants are carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons, and solid particulates. Three human activities generate most air pollution: motor vehicles, industry, and power plants. In all three cases, pollution results from the burning of fossil fuels.

Global Scale Air Pollution
Air pollution concerns geographers at three scales — global, regional, and local. Air pollution may contribute to global warming and damage the atmosphere's ozone layer. It may also be damaging the atmosphere's ozone layer.

Global Warming. Human actions, especially the burning of fossil fuels, may be causing Earth's temperature to rise. The average temperature of Earth's surface has increased by 1° Celsius (2° Fahrenheit) during the past century. Earth is warmed by sunlight that is converted to heat. When the heat tries to pass back through the atmosphere to space, some gets through and some is trapped. A concentration of trace gases in the atmosphere can block or delay the return of some of the heat leaving the surface heading for space. When fossil fuels are burned, one of the trace gasses, carbon dioxide, is discharged. Plants and oceans absorb much of the discharges, but increased fossil-fuel burning during the past 200 years has caused the level of carbon dioxide in the atmosphere to rise by more than one-fourth. Contributing to the warming has been the buildup of carbon dioxide emissions at an annual rate of more than 1 percent, although scientists disagree on whether it caused most or only a small percentage of the warming. The anticipated increase in Earth's temperature, caused by carbon dioxide trapping some of the radiation emitted by the surface, is called the **greenhouse effect**.

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Global warming of only a few degrees could melt the polar ice caps and raise the level of the oceans many meters. Coastal cities would flood. Global patterns of precipitation could shift. The shifts in coastlines and precipitation patterns could require massive migration and be accompanied by political disputes.

Global-Scale Ozone Damage. The stratosphere contains a concentration of **ozone** gas. The ozone layer absorbs dangerous ultraviolet (UV) rays from the Sun. Earth's protective ozone layer is threatened by pollutants called **chlorofluorocarbons (CFCs)**. In 2007, virtually all countries agreed to cease using CFCs, by 2020 in MDCs by 2030 in LDCs.

Regional-Scale Air Pollution

At the regional scale, air pollution may damage a region's vegetation and water supply through acid deposition. Sulfur oxides and nitrogen oxides, emitted by burning fossil fuels, enter the atmosphere, where they combine with oxygen and water. Tiny droplets of sulfuric acid and nitric acid form and return to Earth's surface as acid deposition. When dissolved in water, the acids may fall as acid precipitation — rain, snow, or fog. Acid precipitation damages lakes, killing fish and plants. On land, concentrations of acid in the soil can injure plants by depriving them of nutrients and can harm soil worms and insects. Buildings and monuments made of marble and limestone have suffered corrosion from acid rain. Geographers are particularly interested in the effects of acid precipitation because the worst damage is not experienced at the same location as the emission of the pollutants. Acid rain falling in Ontario, Canada, for example, can be traced to emissions from coal-burning power plants in the U.S. Great Lakes region. Eastern Europe has suffered especially severely from acid precipitation, a legacy of Communist policies that encouraged the construction of factories and power plants without pollution control devices.

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The destruction of trees has harmed Eastern Europe's seasonal water flow. In dense forests, snow used to melt slowly and trickle into rivers. Now, on the barren sites, it melts and drains quickly, causing flooding in the spring and water shortages in the summer. Perhaps the most severe impact is on human life. A 40-year-old man living in Poland's polluted southern industrial area has a life expectancy 10 years less than his father had at the same age. The United States has reduced sulfur dioxide emissions significantly since the 1970s, and many European countries have also made significant cuts. Despite this, acid precipitation continues to damage forests and lakes.

Local Scale Air Pollution

At the local scale, air pollution is especially severe in places where emission sources are concentrated, such as urban areas. Urban air pollution has three basic components:

- **Carbon monoxide:** Produced from incomplete burning in power plants and vehicles.

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- **Hydrocarbons:** Also result from incomplete combustion, as well as evaporation of paint solvents. Hydrocarbons and nitrogen oxides in the presence of sunlight form **photochemical smog**.
- **Particulates:** Include dust and smoke particles.

The severity of air pollution depends on the weather.

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According to the American Lung Association, the two worst U.S. metropolitan areas for concentrations of particulates are Los Angeles and Pittsburgh. Mexico City may have the world's most serious air pollution problem. Progress in controlling urban air pollution is mixed. In MDCs, air has improved where strict clean-air regulations are enforced. Limited emission controls in LDCs are contributing to severe urban air pollution.

Water Pollution
Water serves many human purposes. These uses depend on fresh, clean, unpolluted water, but clean water is not always available, because people also use water for purposes that pollute it. Pollution is widespread, because it is easy to dump waste into a river and let the water carry it downstream where it becomes someone else's problem. Water can decompose some waste, but the volume of discharge often exceeds the capacity of many rivers and lakes to accommodate it.

Water Pollution Sources
Three main sources generate most water pollution:

- **Water-Using Industries**: Steel, chemicals, paper products, and food processing are major industrial polluters of water.
- **Municipal Sewage**: In MDCs, sewers carry wastewater to a municipal treatment plant, where most — but not all — of the pollutants are removed. In LDCs, sewer systems are rare, and wastewater usually drains untreated into rivers and lakes.
- **Agriculture**: Fertilizers and pesticides spread on fields to increase agricultural productivity are carried into rivers and lakes by the irrigation system or natural runoff.

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Point-source pollution enters a stream at a specific location, whereas nonpoint-source pollution comes from a large diffuse area:

- Manufacturers and municipal sewage systems tend to pollute through point sources, such as a pipe from a waste-water treatment plant.
- Farmers tend to pollute through nonpoint sources, such as by permitting fertilizer to wash from a field during a storm.

Point-source pollutants are usually smaller in quantity and much easier to control.

Impact on Aquatic Life
Aquatic plants and animals consume oxygen, but so do the decomposing organic waste that humans dump into the water. The oxygen consumed by the decomposing organic waste constitutes the **biochemical oxygen demand (BOD)**. If too much waste is discharged into the water, the water becomes oxygen-starved and fish die. When runoff carries fertilizer from farm fields into streams or lakes, the fertilizer nourishes excessive aquatic plant production that consumes too much oxygen. Either type of pollution unbalances the normal oxygen level, threatening aquatic plants and animals. Some of the residuals may become concentrated in the fish, making them unsafe for human consumption. Many factories and power plants use water for cooling and then discharge the warm water back into the river or lake. Fish adapted to cold water, such as salmon and trout, might not be able to survive in the warmer water.

Wastewater and Disease
Since passage of clean water laws, most treatment plants meet high water-quality standards.

Improved treatment procedures have resulted in cleaner rivers and lakes in MDCs. The Thames was once a major food source for Londoners, but during the Industrial Revolution it became the principal location for dumping waste. The fish died, and the water grew unsafe to drink. The British government began a massive cleanup during the 1960s to restore the Thames to health. A salmon was caught in the Thames just upstream from London in 1982, the first since 1833.

In LDCs, sewage often flows untreated directly into rivers. The drinking water, usually removed from the same rivers, may be inadequately treated as well. Waterborne diseases such as cholera, typhoid, and dysentery are major causes of death. Some LDCs regard water pollution as a small price to pay for participating in a global economy.

Land Pollution
When we consume a product, we also consume an unwanted byproduct, the container in which the product is packaged. About 2 kilograms (4 pounds) of solid waste per person is generated daily in the United States.

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Paper products, such as corrugated cardboard and newspapers, account for the largest percentage of solid waste in the U.S., especially among residences and retailers.
Even consumers who carefully dispose of solid waste are contributing to a major pollution problem.

Solid Waste Disposal
The **sanitary landfill** is by far the most common strategy for disposal of solid waste in the United States. We *disperse* air and water pollutants into the atmosphere, rivers, and eventually the ocean, but we *concentrate* solid waste in thousands of landfills. Chemicals released by the decomposing solid waste can leak from the landfill into groundwater. This can contaminate water wells, soil, and nearby streams. The number of landfills in the U.S. has declined by three-fourths since 1990. Better compaction methods and expansion of large regional landfills have provided expanded capacity. Some communities now pay to use landfills elsewhere. Incineration and recycling have both increased rapidly. Burning the trash reduces its bulk by about three-fourths, demanding far less landfill space. Incineration also provides energy that generates electricity. Burning releases some toxins into the air, and some remain in the ash.

Hazardous Waste
Disposing of hazardous waste is especially difficult. Hazardous wastes include heavy metals (including mercury, cadmium, and zinc), PCB oils from electrical equipment, cyanides, strong solvents, acids, and caustics. If poisonous industrial residuals are not carefully placed in protective containers, the chemicals may leach into the soil and contaminate groundwater or escape into the atmosphere. Companies in the United States that release chemicals classified as toxic by the E.P.A. must report the amounts released. About 47 million tons of hazardous wastes were discharged in the United States in 2007.

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Some European and North American firms have tried to transport their waste to West Africa, often unscrupulously.

Key Issue 3. Why Are Resources Being Reused?

- **Renewing resources**

- **Recycling resources**

Depletion and destruction of resources can be reduced through reuse. Renewable resources can be substituted for nonrenewable ones. Recycling unwanted resources can replace the discharging of these products into the environment.

Renewing Resources
Energy poses an especially strong challenge in substituting renewable energy resources for nonrenewable ones. Although renewable resources can be harnessed for energy, continued reliance on petroleum, natural gas, and coal continues to be the cheaper alternative.

Nuclear Energy
The big advantage of nuclear power is the large amount of energy released from a small amount of material. Nuclear power supplies about one-sixth of the world's electricity. Europe and the U.S. are each responsible for generating one-third of the world's nuclear power, and about 30 countries make some use of nuclear power. The countries most highly dependent on nuclear power are clustered in Europe. Dependency on nuclear power varies widely among U.S. states. Twenty states and the District of Columbia have no nuclear power plants. Nuclear power presents serious problems.

Potential Accidents. A nuclear power plant produces electricity from energy released by splitting uranium atoms in a controlled environment, a process called **fission**. One product of all nuclear reactions is **radioactive waste**.

Nuclear power plants cannot explode, like a nuclear bomb, however, it is possible to have a runaway reaction, which overheats the reactor, causing a meltdown, possible steam explosions, and scattering of radioactive material into the atmosphere. This happened in 1986 at Chernobyl in the north of Ukraine, near the Belarus border. Half of the eventual victims may be residents of European countries other than Ukraine and Belarus.

Radioactive Waste. When nuclear fuel fissions, the waste is highly radioactive and lethal, and it remains so for many years. Plutonium can be harvested from it for making nuclear weapons. No one has yet devised permanent storage for radioactive waste. It must be isolated for several thousand years. The United States is Earth's third-largest country in land area, yet it has failed to find a suitable underground storage site because of worry about groundwater contamination.

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Bomb Material. Nuclear power has been used in warfare twice, in August 1945, when the United States dropped an atomic bomb on first Hiroshima and then Nagasaki, Japan. No government has since dared to use them in a war, because leaders have recognized that a full-scale nuclear conflict could terminate human civilization. Russia and the U.S. each have several thousand nuclear weapons; China, France and the United Kingdom have several hundred; India and Pakistan have several dozen; and North Korea has a handful. Israel is suspected of having nuclear weapons, but has not admitted to it. Iran has been developing the capability. Diffusion of nuclear programs to countries sympathetic to terrorists has been particularly worrying to the rest of the world.

Limited Uranium Reserves. Like fossil fuels, uranium is a nonrenewable resource. Proven reserves are limited — about 124 years at current rates of use. One-fourth of the proven reserves are in Australia and one-sixth are in Kazakhstan. Uranium ore naturally contains only 0.7 percent U-235; a greater concentration is needed for power generation. A **breeder reactor** turns uranium into a renewable resource by generating plutonium, also a nuclear fuel. However, plutonium is more lethal than uranium. It is also easier to fashion into a bomb. Because of these risks, few breeder reactors have been built, and none are in the United States.

High Cost. Nuclear power plants cost several billion dollars to build, primarily because of elaborate safety measures. Uranium is mined in one place, refined in another, and used in still another. Generating electricity from nuclear plants is much more expensive than from coal burning plants. The future of nuclear power has been seriously hurt by the combination of high risk and cost. Some countries in North America and Western Europe have curtailed construction of new plants. On the other hand, countries without nuclear power are moving toward introducing it, including Poland, Turkey, Indonesia, and Vietnam.

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Australia, with the most extensive reserves of uranium, is debating expansion. Advances in safety and reactor technology, combined with the high cost of other power sources, are driving the renewed interest.

Nuclear Fusion. Some nuclear power issues could be addressed through nuclear **fusion**, which is the fusing of hydrogen atoms to form helium. Fusion releases spectacular amounts of energy, but fusion can occur only at very high temperatures. Alternatives such as fusion do not offer immediate solutions to energy shortages in the twenty-first century but may become more practical if the price of current energy resources substantially rises.

Leading Renewable Energy Sources

The two leading renewable energy sources currently are biomass and hydroelectric. Geothermal, wind, and solar are also currently used but are less common.

Biomass. More than one-half of renewable energy comes from biomass, including wood and crops. When carefully harvested, wood is a renewable resource that can be used to generate electricity and heat. Crops such as sugarcane, corn, and soybeans, can be processed into motor vehicle fuels. The potential for increasing the use of biomass for fuel is limited, for several reasons:

- When wood is burned for fuel instead of being left in the forest, the fertility of the forest may be reduced.
- Burning biomass may be inefficient, because the energy used to produce the crops may be as much as the energy supplied by the crops.
- Biomass already serves other essential purposes other than energy, such as providing much of Earth's food, clothing, and shelter.

Hydroelectric Power. Water has been a source of mechanical power since before recorded history. It turned water wheels to operate machines. Over the last hundred years, the energy of moving water has been used to generate electricity, called **hydroelectric power**. Hydroelectric power is the world's second most popular source of electricity, after coal, supplying about a fourth of worldwide demand. Many LDCs depend on hydroelectric power for most of their power.

China is the world's leading producer of hydroelectric power. Unfortunately, its Three

Gorges dam, under construction across the Yangtze River, is widely regarded as an environmental disaster for the resulting decline in water quality in the river, endangerment of wildlife, and extinction of rare species of vegetation in a region known for biodiversity.

Wind Power. Wind has also long been a source of energy, the most obvious being sailboats and windmills. One-third of the U.S. is considered windy enough to make wind power economically feasible. Twenty percent of Denmark's electricity is wind generated. Construction of a windmill modifies the environment much less severely than a dam. Some oppose windmills because they can be noisy and lethal for birds and bats, and can constitute a visual blight when constructed on mountaintops or offshore in places of outstanding beauty.

Geothermal Energy. Natural nuclear reactions make the Earth's interior hot. In volcanic areas hot rocks can encounter groundwater producing steam that can be tapped by wells. Energy from this hot water or steam is called **geothermal energy**. Harnessing geothermal energy is most feasible at the rifts along Earth's surface where crustal plates meet.

Solar Energy

The ultimate renewable resource is solar energy supplied by the sun. Solar sources currently supply the U.S. with only 1 percent of electricity, but the potential for growth is limitless. The sun's energy is free and ubiquitous and cannot be exclusively owned, bought, or sold; it does not damage the environment or cause pollution.

Passive Solar Energy. Solar energy is harnessed through either passive or active means. **Passive solar energy systems** capture energy without special devices. Reliance on passive solar energy increased during the nineteenth century when construction innovations first permitted hanging of massive glass "curtains" on a thin steel frame. With electricity and petroleum cheap and abundant after World War II and through most of the twentieth century, passive solar energy rarely played a major role in construction of homes and commercial buildings. In recent years building construction and remodeling have made more use of passive solar energy through advances in glass technology.

Active Solar Energy. Active solar energy systems collect solar energy and convert it either to heat energy or to electricity. In direct electric conversion, solar radiation is captured with **photovoltaic cells** which convert light energy to electrical energy. (464) In indirect electric conversion, solar radiation is first converted to heat, then to electricity. In heat conversion, solar radiation is concentrated with large reflectors and lenses to heat water or rocks.

Generating Electricity Through Solar. Solar power can be produced at a central station and distributed by an electric company, as coal and nuclear-generated electricity is now supplied. With coal still relatively cheap, there is little interest in solar technology. In MDCs, solar electricity is used in spacecraft, calculators, and sites where conventional power is unavailable. In LDCs, the largest and fastest-growing market for photovoltaic cells includes the 2 billion people who lack electricity, especially residents of remote villages. But the cost of cells must drop and their efficiency must improve for solar power to expand rapidly.

Renewable Energy in Motor Vehicles

The most serious obstacle to decreasing reliance on nonrenewable energy is its importance as motor vehicle fuel. Several alternative sources of fuel are becoming available.

Batteries. Battery power was popular in early motor vehicles, especially in 1900 in large cities of the northeast where their relative quietness and cleanliness made them popular as taxicabs. Women preferred them because they were easy to start. The main shortcomings of the electric car in the early 1900s remain unchanged a century later. Electric-powered vehicles have a more limited range, cost more to operate, and recharging the batteries can take several hours. To address these issues, carmakers offer a variety of vehicles that combine electric and gasoline power.

Biofuels. Motor-vehicle fuel, known as ethanol, can be produced from biomass material, specifically the sugars found in many crops. Corn is the principal source of ethanol in the United States. However to grow and process the corn takes a lot of energy, supplied primarily by fossil fuels, so using ethanol may not actually reduce dependency on fossil fuels. Because of the limitations of using corn, engineers are looking at other sources of biofuels, such as sugarcane in Brazil.

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Some vehicles with diesel engines can be run on biodiesel, a fuel made from vegetable oil and fats.

Hydrogen Fuel Cells. Hydrogen fuel cells convert hydrogen and oxygen into water, producing electricity and heat in the process. The oxygen for the fuel cell reaction comes from the air, so it is free and ubiquitous. For motor vehicles, getting tanks of liquid or gaseous hydrogen to motorists will require a new distribution system. Increasing and wildly fluctuating petroleum prices have stimulated interest in alternative-fuel vehicles.

Recycling Resources

Recycling increased in the United States from 7 percent of all solid waste in 1970 to 10 percent in 1980, 17 percent in 1990, and 33 percent in 2007. The amount of solid waste generated by Americans increased by 54 million tons between 1990 and 2007, and the amount recycled increased by 51 million tons, so about the same amount went into landfills or incinerators. The percentage of recovered materials varies widely by product.

Recycling Collection

Recycling involves two main series of activities. First, materials that would otherwise be "thrown away" are collected and sorted.

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Then the materials are manufactured into new products for which a market exists.

Pickup and Processing. Recyclables are collected in four primary methods: curbside, drop-off centers, buyback centers, and deposit programs. Regardless of the collection method, recyclables are sent to a materials recovery facility to be sorted and prepared into marketable commodities for manufacturing.

Manufacturing. Once cleaned and separated, the recyclables are ready to be manufactured into a marketable product. Four major manufacturing sectors accounted for more than half of the recycling activity — paper mills, steel mills, plastic converters, and iron and steel foundries.

- **Paper:** Most types can be recycled; the key is collecting large quantities of clean, well-