Concentration would seem to eliminate solid-waste pollution, but it may only hide it—temporarily. 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 United States has declined by three-fourths since 1990. Thousands of small-town "dumps" have been closed and replaced by a small number of large regional ones. Better compaction methods, combined with expansion in the land area of some of the larger regional ones, have resulted in expanded landfill capacity. At the same time, the two principal alternatives to disposing solid waste in landfills—incineration and recycling—have both increased rapidly.

Some communities now pay to use landfills elsewhere. New Jersey and New York are two states that regularly try to dispose of their solid waste by transporting it out of state. New York City exports 25,000 tons of trash a day to other communities. Passaic County, New Jersey, hauls waste 400 kilometers (250 miles) west to Johnstown, Pennsylvania. San Francisco trucks solid waste to Altamont, California, 100 kilometers (60 miles) away.

**INCINERATION.** Burning the trash reduces its bulk by about three-fourths, and the remaining ash demands far less landfill space. Incineration also provides energy—the incinerator's heat can boil water to produce steam heat or to operate a turbine that generates electricity. Given the shortage of space in landfills, the percentage of solid waste that is burned has increased rapidly during the past three decades, to one-sixth of solid waste.

However, solid waste, a mixture of many materials, may burn inefficiently. Burning releases some toxins into the air, and some remain in the ash. Thus solving one pollution problem may increase another.

---

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. These may have been unwanted by-products generated in manufacturing or discarded after usage. 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. Breathing air or consuming water contaminated with toxic wastes can cause cancer, mutations, chronic ailments, and even immediate death.

Burial of wastes was once believed to be sufficient to handle the disposal problem, but many of the burial sites have leaked. One of the most notorious is Love Canal, near Niagara Falls, New York. The Hooker Chemicals and Plastic Company buried toxic wastes in metal drums during the 1930s. A school and several hundred homes were built on the site in 1953. Erosion eventually exposed the metal drums, and in 1976 they began to give off a strong stench and slime oozed from them.

Residents at Love Canal reported a high incidence of liver ailments, nervous disorders, and other health problems. After four babies were born with birth defects on the same block, New York State officials relocated most of the families and began an expensive cleanup effort. Love Canal is not unique. Toxic wastes have been improperly disposed of at thousands of dumps.

Companies in the United States that release chemicals classified as toxic by the Environmental Protection Agency (E.P.A.) must report the amounts released. About 30 million tons of hazardous wastes were discharged in the United States in 2003. Five companies were responsible for at least 1 million tons each: BP Products in Texas City, Texas; Rubicon in Geismar, Louisiana; Cytec Industries in Waggaman, Louisiana; DuPont in Pass Christian, Mississippi; and BP Amoco in Lima, Ohio.

As toxic-waste disposal sites become increasingly hard to find, some European and North American firms have tried to transport their waste to West Africa, often unscrupulously. Some firms have signed contracts with West African countries, whereas others have found isolated locations to dump waste without official consent.

---

**KEY ISSUE 3**

**Why Are Resources Reusable?**

- Renewing resources
- Recycling resources

Depletion and destruction of resources can be reduced through reusing resources. Nonrenewable resources can be replaced with renewable ones. The discharging of unwanted by-products into the environment can be replaced with the recycling of them into resources.
Renewing Resources

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

About 6 percent of energy consumed in the United States is generated by renewable sources. Biomass and hydroelectric account for around 45 percent each of renewable sources, geothermal 6 percent, wind 2 percent, and solar 1 percent. Fusion is not a practical source of renewable energy at this time but may be in the future.

Leading Renewable Energy Sources

The two leading renewable energy sources currently are biomass and hydroelectric. Geothermal and wind are also used, but less frequently. Fusion is not a practical source at this time but may be in the future.

BIOMASS. Forms of biomass include wood and crops. When carefully harvested in forests, wood is a renewable resource. The waste from processing wood, such as building construction and demolition, is also available. Wood can be used to generate electricity and heat.

Crops such as sugarcane, corn, and soybeans can be processed into motor-vehicle fuels. Brazil in particular makes extensive use of biomass to fuel its cars and trucks.

The potential for increasing the use of biomass for fuel is limited for several reasons. Burning biomass may be inefficient, because the energy used to produce the crops may be as much as the energy supplied by the crops. When wood is burned for fuel instead of being left in the forest, the fertility of the forest may be reduced. The most important limitation on using biomass for energy is that it already serves other essential purposes, 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, and the rotational motion was used to grind grain, saw timber, pump water, and 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 one-fourth of worldwide demand. Many LDCs depend on hydroelectric power for the vast majority of their electricity (Figure 14–16). Brazil is the most populous country to depend primarily on hydroelectric power. Among MDCs, Canada gets about half of its electricity from hydroelectric power. China and the United States are also leading producers but are less dependent on the resource. The United States, which obtains only about 3 percent of its energy through hydroelectric power, anticipates the percentage to decline, because few acceptable sites to build new dams remain.

Hydroelectric power has drawbacks. Dams may flood formerly usable land, cause erosion, and upset ecosystems. Political problems can result from building dams on rivers that flow through more than one country. Turkey’s recently built dam on the Euphrates River was strongly opposed by Syria and Iraq, through which the river also passes. The new dam diverts too much water from the river and makes its water saltier.

WIND POWER. Wind has also long been a source of energy, the most obvious being sailboats to travel and windmills to grind grain. Like moving water, moving air can turn a turbine.

Hundreds of wind “farms” consisting of dozens of windmills have been constructed across the United States. One-third of the country is considered windy enough to make wind power economically feasible (Figure 14–17). North Dakota, Texas, Kansas, South Dakota, and Montana are considered the five states with the most potential for wind power. Twenty percent of Denmark’s electricity is being generated through wind power.

The benefits of wind-generated power seem irresistible. Construction of a windmill modifies the environment much less severely than construction of a dam across a river. Wind power has a greater potential for increased use because only a small portion of the potential resource has been harnessed. However, wind power has divided the environmental community. Some oppose construction of windmills because they can be noisy and lethal for birds and bats. They also can be visually
blighting when constructed on mountaintops or offshore of places of outstanding beauty.

**GEOTHERMAL ENERGY.** Earth’s interior is hot from natural nuclear reactions. Toward the surface, heat is especially pronounced in volcanic areas. The hot rocks can encounter groundwater, producing heated water or 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. These rifts are also the sites of many earthquakes and volcanoes. Geothermal energy is being tapped in several locations, including California, Italy, New Zealand, and Japan, and other rift sites are being explored. Iceland and Indonesia make extensive use of this resource. Ironically, in Iceland, an island named for its glaciers, nearly all homes and businesses in the capital of Reykjavik are heated with geothermal steam.

**NUCLEAR FUSION.** Some nuclear power problems could be solved with **nuclear fusion**, which is the fusing of hydrogen atoms to form helium. Fusion releases spectacular amounts of energy—a gram-sized amount of hydrogen releases the energy of thousands of tons of coal. But fusion can occur only at very high temperatures (millions of degrees). Such high temperatures have been briefly achieved in hydrogen bomb tests but not on a sustained basis in a power-plant reactor, given present technology.

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 sources substantially rises. Earth possesses a variety of energy resources, but the era of dependency on nonrenewable fossil fuels for energy will constitute a remarkably short period of human history.

**Solar Energy**

The ultimate renewable resource is solar energy supplied by the Sun. Solar sources currently supply the United States with only a tiny percentage of total energy, 0.06 percent, but growth is limitless. The Sun’s remaining life is estimated at 5 billion years, and humans appear incapable of destroying or depleting
that resource. The Sun's energy is free and ubiquitous and cannot be exclusively owned, bought, or sold by any particular individual or enterprise. Utilizing the Sun as a resource does not damage the environment or cause pollution, as does the extraction and burning of nonrenewable fossil fuels.

**PASSIVE SOLAR ENERGY.** Solar energy is harnessed through either passive or active means. Passive solar energy systems capture energy without special devices. Passive solar energy systems use south-facing windows and dark surfaces to heat and light buildings on sunny days. The Sun's rays penetrate the windows and are converted to heat. Humans act as passive solar energy collectors when they are warmed by sunlight. Dark objects absorb more energy, so wearing dark clothing warms a person even more when exposed to sunlight.

Reliance on passive solar energy increased during the nineteenth century when construction innovations first permitted the hanging of massive glass "curtains" on a thin steel frame. One popular type of building that utilized the new glass and steel technology in the nineteenth century was the greenhouse, in which people could grow and view vegetation that required more warmth to flourish than the local climate permitted. Early skyscrapers made effective use of passive solar energy.

With electricity and petroleum cheap and abundant, passive solar energy did not play a major role in construction of homes and commercial buildings through most of the twentieth century. Consumers looked for alternative energy sources during World War II when fossil fuels were rationed. A major glass manufacturer, Libbey-Owens-Ford Glass Co., responded by publishing a book entitled *Your Solar House* in 1947. But resumption of abundant supplies of cheap petroleum after World War II killed consumer demand for solar energy and conservation for a generation.

Interest in passive solar energy resumed when petroleum prices rapidly escalated during the 1970s. The largest contribution to increased use of passive solar energy has been made through advances in glass technology, including double- and triple-pane windows with much higher insulating values, low-E (low emissivity) glass coated to let heat in but not out, windows filled with argon or other gases to increase insulating values beyond windows with just air, and phase-change technologies that can switch from opaque to translucent when a voltage is applied to them.

**ACTIVE SOLAR ENERGY.** Active solar energy systems collect solar energy and convert it either to heat energy or to electricity. The conversion can be accomplished either directly or indirectly.

In direct electric conversion, solar radiation is captured with photovoltaic cells, which convert light energy to electrical energy. Bell Laboratories invented the photovoltaic cell in 1954. Each cell generates only a small electric current, but large numbers of them wired together produce significant electricity.

Photovoltaic cells are made primarily of silicon, the second most abundant element in Earth's crust, also used in computers. When the silicon is combined with one or more other materials, it exhibits distinctive electrical properties in the presence of sunlight, known as the photovoltaic effect. Electrons excited by the light move through the silicon, producing direct current (DC) electricity.

In indirect electric conversion, solar radiation is first converted to heat, then to electricity. The Sun's rays are concentrated by reflectors onto a pipe filled with synthetic oil. The heat from the oil-filled pipe generates steam to run turbines. In heat conversion, solar radiation is concentrated with large reflectors and lenses to heat water or rocks. These store the energy for use at night and on cloudy days. A place that receives relatively little sunlight can still use solar energy by using more reflectors and lenses and larger storage containers.

**Uses for Renewable Energy**

Efforts to utilize more renewable energy are focused on two sectors—electricity and motor vehicles. Alternatives to fossil
fuels are currently available in both cases, though the cost is too high to be competitive in most situations.

**ELECTRICITY.** In MDCs, solar energy is used primarily as a substitute for electricity in heating water. Rooftop devices collect, heat, and store water for apartment buildings in Israel and Japan and individual homes in the United States. Solar-generated electricity is used in spacecraft, light-powered calculators, and at remote sites where conventional power is unavailable, such as California's Mojave Desert.

Solar power can be produced at a central station and distributed by an electric company, as coal- and nuclear-generated electricity is now supplied. However, public and private utility companies have had little interest in solar technology with coal still relatively cheap and investment in nuclear facilities already substantial. The initial cost of installing a solar water heater is higher than hooking into the central power system but may be justified if an individual plans to stay in the same house for a long time.

The largest and fastest-growing market for photovoltaic cells includes the two billion people who lack electricity in LDCs, especially residents of remote villages. For example, in Kenya, more homes have been electrified in recent years using photovoltaic cells than by hooking up to the central power grid. In Morocco, solar panels are sold in bazaars and open markets, next to carpets and tinware.

The cost of cells must drop and their efficiency must improve for solar power to expand rapidly, with or without government support. Solar energy will become more attractive as other energy sources become more expensive. A bright future for solar energy is indicated, for petroleum companies now own the major U.S. manufacturers of photovoltaic cells.

**MOTOR VEHICLES.** The most serious obstacle to decreasing reliance on nonrenewable energy is its importance as automotive fuel. Electric vehicles have been introduced to the market in recent years but have been withdrawn. Emphasis is now being placed on fuel cell technology.

Of the 4,000 cars sold in the United States in 1990, 38 percent were powered by electricity, 40 percent by steam, and only 22 percent by gasoline. The electric car was especially popular in large cities of the Northeast, such as New York and Philadelphia, where their relative quietness and cleanliness made them popular as taxicabs. Women also preferred electric cars because they were easier to start than gasoline- or steam-powered ones.

The main shortcomings of the electric car in the early 1990s remain unchanged a century later. Compared to gasoline, the electric-powered vehicle has a more limited range and costs more to operate. The use of electric vehicles is expanding in MDCs, primarily to reduce air pollution rather than to conserve the nonrenewable resource of petroleum.

Limitations with electric power have led motor-vehicle producers to consider fuel cells instead. Fuel cells convert hydrogen and oxygen into water, producing electricity and heat in the process. The electricity can be used to power motors or other electrical devices.

The oxygen for the fuel cell reaction comes from the air so it is free and ubiquitous. Obtaining the hydrogen is more problematic. Hydrogen can be extracted from natural gas, propane, methanol, and other fuels, but the process generates heat and other gases and depends on nonrenewable sources. Getting tanks of liquid or gaseous hydrogen to motorists will require a new distribution system.

As long as motorists perceive petroleum to be cheap and abundant, alternative-fuel vehicles have limited popularity. It will take a major increase in world petroleum prices or disruption in supplies to bring alternative fuel vehicles to the market in large numbers. If that happens, by the middle of the twenty-first century large gasoline-powered vehicles would be limited to specialized tasks—or consigned to museums.

**Recycling Resources**

Unwanted by-products are usually “thrown away,” perhaps in a “trash can.” **Recycling** is the separation, collection, processing, marketing, and reuse of the unwanted material. 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 32 percent in 2005.

As a result of recycling, about 79 million of the 238 million tons of solid waste generated in the United States in 2005 did not have to go to landfills and incinerators, compared to 34 million of 200 million tons generated in 1990. In other words, the amount of solid waste generated by Americans increased by 38 million tons between 1990 and 2005, and the amount recycled increased by 45 million tons, so 7 million tons less were going into landfills or incinerators.

The percentage of recovered materials varies widely by product: around 60 percent of yard trimmings and 50 percent of paper products are recycled, compared to only 5 percent of plastic and 2 percent of food scraps; and 10 to 20 percent of glass, leather, rubber, and textiles are recycled.

---

*Solar energy is increasingly used in Africa where it is not economical to string wires for electricity or telephone service. Here a solar-powered oven is being used to cook food in Zimbabwe.*
Recycling Collection

Recycling involves two main series of activities. First, materials that would otherwise be “thrown away” are collected and sorted. Then the materials are manufactured into new products for which a market exists.

**PICK-UP AND PROCESSING.** Recyclables are collected in four primary methods—curbside, drop-off centers, buy-back centers, and deposit programs.

Curbside programs require consumers to place recyclables at the curb in a separate container than the nonrecycled trash at a specified time each week, either at the same or different time as the other trash. The trash collector usually supplies homes with specially marked containers for the recyclable items.

Drop-off centers are sites for individuals to leave recyclable materials, typically several large containers placed at a central location. A separate container is designated for each type of recyclable material. The containers are periodically emptied by a processor or recycler but are otherwise left unattended.

Buy-back centers are commercial operations that pay consumers for recyclable materials, especially aluminum cans, but also sometimes plastic containers and glass bottles. These materials are usually not processed at the buy-back center.

Deposit programs involve the return of glass and aluminum containers to retailers. The price a consumer pays for a beverage includes a deposit fee of $0.05 or $0.10 that the retailer refunds when the container is returned.

Regardless of the collection method, recyclables are sent to a materials recovery facility to be sorted and prepared into marketable commodities for manufacturing. Recyclables are bought and sold just like any other commodity: typical prices in recent years have been $30 per ton for clear glass, $90 per ton for corrugated paper. Prices for the materials change and fluctuate with the market.

**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.

Common household items that contain recycled materials include newspapers and paper towels; aluminum, plastic, and glass soft drink containers; steel cans; and plastic laundry detergent bottles. Recycled materials are also used in such industrial applications as recovered glass in roadway asphalt (“glassphalt”) or recovered plastic in carpeting, park benches, and pedestrian bridges.

Most types of paper can be recycled. Newspapers have been recycled profitably for decades, and recycling of other paper is growing, especially computer paper. Rapid increases in the price of virgin paper pulp prices have stimulated construction of more plants capable of using waste paper. The key to recycling is collecting large quantities of clean, well-sorted, uncontaminated, and dry paper.

The principal obstacle to the recycling of plastic is that plastic types must not be mixed, yet it is impossible to tell one type from another by sight or touch. Even a small amount of the wrong type of plastic can ruin the melt. The plastic industry has responded to this problem by developing a series of numbers marked inside triangles on the bottom of containers. Types 1 and 2 are commonly recycled, and the others generally are not.

Glass is 100 percent recyclable and can be used repeatedly with no loss in quality. The process of creating new glass from old is also extremely efficient, producing virtually no waste or unwanted by-products. However, although unbroken clear glass is valuable, mixed color glass is nearly worthless, and broken glass is hard to sort.

Scrap aluminum is readily accepted for recycling, although other metals are rarely accepted. The principal source of recycled aluminum is beverage containers. Aluminum cans began to replace glass bottles for beer during the 1950s and for soft drinks during the 1960s.

Other Pollution by Reduction Strategies

In addition to recycling, two other basic strategies can reduce pollution. The amount of waste discharged into the environment can be reduced, or the capacity of the environment to accept discharges can be expanded.

**REDUCING DISCHARGES.** Pollution can be prevented if the amount of waste being discharged into the environment is reduced to a level that the environment can assimilate. Although consumers
purchase more “throw-away” packages than in the past, the pack-
aging material is much less bulky. Glass bottles weigh less today
than a generation ago, as do plastic jugs. Higher manufacturing
and shipping costs following the 1973 energy crisis induced com-
panies to cut costs by reducing the bulk of their packaging.

The mix of various inputs can be adjusted to produce a
higher ratio of product to waste. For example, gasoline for
motor vehicles once contained lead. But most of the lead was
discharged through the exhaust pipe and contributed to air pol-
lution. To reduce the generation of lead—once a significant
waste—automakers modified engines so that they operate on
unleaded instead of leaded gasoline.

The amount of waste can also be reduced if the production
system produces less of the product—or if production ceases
altogether—because of lower consumer demand. The creation
of fewer products would result in the production of less waste as
well. If consumers drive less, then they will use less gasoline and
therefore generate less pollution.

Emissions-trading systems can reduce discharges, especially
into the atmosphere. To reduce sulfur dioxide discharges, the
United States introduced a market through an amendment to
the 1990 Clean Air Act. Power companies can buy and sell
allowances to emit sulfur dioxide. Dirty power companies have
found it cheaper to install pollution-control devices to reduce
pollution and sell some of their allowances. In Canada, Ontario’s
emissions reduction trading sets emissions caps and creates a
market for trading allowances and credits within the caps.

The Chicago Climate Exchange opened in 2003 to promote
reduction of greenhouse gases. Companies participating in
the Chicago Climate Exchange set voluntary targets for emissions
reduction. If the company exceeds its targets, it can trade or sell
the excess reduction to another participating company that isn’t
meeting its targets.

**Increasing Environmental Capacity.** The second
way to handle pollution is to increase the capacity of the envi-
noment to accept the discharges. The capacity of air, water,
and land to accept waste is not fixed but varies among places
and at different times.

Adding a particular amount of wastewater to a stream may or
may not constitute pollution, depending on the flow of the water.
A deep, fast-flowing river has a greater capacity to absorb waste-
water than a shallow, slow-moving one. Wastewater can be stored
when the river level is low and released when the river is high.

Similarly, exhaust released into stagnant air irritates, whereas
exhaust released in windy conditions is quickly dispersed. Indus-
tries and utilities reduce local air pollution by building taller
smokestacks, which better disperse gases at greater heights.

Environmental capacity can also be increased by transforming
the waste so that it is discharged into a resource that has the capaci-
ty to assimilate it. Matter can be transformed among gaseous,
liquid, and solid states and discharged into air, water, or land.

For example, a coal-burning power plant can discharge gases
into the atmosphere, causing air pollution. To reduce air pollu-
tion, wet scrubbers are installed to wash particulates from the gas
before it is released to the atmosphere. Wet scrubbers capture the
particulates in water, which then can be discharged into a stream.
If the stream is polluted by the discharge, then the wastewater can
be cleaned in a settling basin where the particulates drop out. This
transforms the residue into a solid waste for disposal on land.

**A Coking Plant: Using All Reduction Strategies.**
A coking plant provides an example of applying all pollution-
reduction strategies—recycling, reducing discharges, and
increasing environmental capacity (Figure 14–18). The main
input into a coking plant is a mixture of coal types, and the
intended product is coke, which becomes an input in steel pro-
duction. The coal is placed in a blast furnace and cooked at very
high temperatures to form coke. Four unwanted by-products result—gases, tars, oils, and heat.

Discharging the heat into the environment can cause air pollu-
tion. To reduce air pollution from the heat, a coking plant
increases the capacity of the environment to accept discharges in
two ways. First, the hot coke is taken to a quench station and
doused with water to cool it. This process transforms the resid-
ual (hot gas) into a liquid (dirty water) as well as another gas (steam).
In this way, the waste is transformed and discharged into different
parts of the environment. Then the steam is discharged into the
environment from a tall smokestack, an example of making more
efficient use of whatever initially received the discharge (air).

The coking plant also minimizes pollution by reducing dis-
charges. The dirty water produced at the quench station is
reused to cool more hot coke, an example of recycling in the
same production process. Meanwhile, the three unwanted
by-products from the blast furnace (other than heat)—gases,
tars, and oils—are captured and sold to other companies for
recycling in other processes. The other alternative for reducing
discharges—changing the mix of coal used as inputs—is also
employed, because the amount of gases emitted by the burning
of coke varies depending on the mix of coal.

**Comparing Pollution Reduction Strategies**
Relying on an increase in the capacity of the environment to
accept discharges is risky. Because we do not always know the
environment’s capacity to assimilate a particular waste, we are
likely to exceed it at times. Recent history is filled with examples
of wastes discharged in the environment with the belief that they
would be dispersed or isolated safely—CFCs in the stratosphere,
garbage offshore, and toxic chemicals beneath Love Canal.

Dispersed wastes may remain harmful. Tall smokestacks
built to reduce sulfur dioxide discharges around coal-burning
industries and metal smelters were successful at dispersing sul-
fur over a larger area. But the result of the dispersal was that
acid precipitation (containing sulfur) fell hundreds of kilo-
metros away, polluting vegetation and lakes over a wide area.

Many pollutants are mobile. They often travel from air to
soil, or soil to water. A pollutant like sulfur dioxide might exist
at tolerable levels in the air, but it damages trees when it accumu-
lates in the soil. In view of the many uncertainties associated
with increasing environmental capacity, reducing discharges
into the environment (by either changing the production
process or recycling) is usually the preferred alternative.

Although the environment has the capacity to accept some
discharges, consumers must learn to use this environmental
capacity most efficiently. At the same time, consumers must
learn to waste less, either by reducing the consumption of products that result in waste or by recycling more. With careful management, we can enjoy the benefits of both industrial development and a cleaner, safer environment.

**KEY ISSUE 4**

**Why Can Resources Be Conserved?**

- Sustainable development
- Biodiversity

Because it is one part natural science and one part social science, geography is especially sensitive to the importance of protecting the natural environment while meeting human needs. "Conservation" is a concept that reflects balance between nature and society.

Conservation is the sustainable use and management of natural resources such as wildlife, water, air, and Earth deposits to meet human needs, including food, medicine, and recreation. Renewable resources such as trees are conserved if they are consumed at a less rapid rate than they can be replaced. Nonrenewable resources such as fossil fuels are conserved if remaining reserves are maintained for future generations.

Conservation differs from preservation, which is maintenance of resources in their present condition, with as little human impact as possible. The value of nature does not derive from human needs and interests, but from the fact that every plant and animal living on Earth has a right to exist and should be preserved regardless of the cost.

The concept of preservation does not regard nature as a resource for human use. In contrast, conservation is compatible with development but only if natural resources are utilized in a careful rather than a wasteful manner. An increasingly important approach to careful utilization of resources is sustainable development, based on promotion of biodiversity.

**Sustainable Development**

Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs," according to the United Nations. Through sustainable development, humans can improve their quality of life while protecting Earth's resources for the benefit of future generations.

The concept of sustainable development is based on limiting the use of renewable resources to the level at which the environment can continue to supply them indefinitely. The amount of timber cut down in a forest or the number of fish removed from a body of water can be controlled at a level that does not reduce future supplies.

**Sustainability and Economic Growth**

The UN's "sustainable development" was defined in the 1987 Brundtland Report, named for the World Commission on Environment and Development's chair, Gro Harlem Brundtland, former Prime Minister of Norway. Titled *Our Common Future*, the Brundtland Report was a landmark in recognizing sustainable development as a combination of environmental and economic elements.
The Brundtland Report argued that sustainable development had to recognize the importance of economic growth while conserving natural resources. Environmental protection, economic growth, and social equity are linked because economic development aimed at reducing poverty can at the same time threaten the environment.

Plans to protect the environment would fail unless LDCs could promote economic growth in order to meet basic needs of employment, food, energy, water, and sanitation. "Environment and development are not separate challenges: they are inexorably linked," concluded the Brundtland Report. "Development cannot exist on a deteriorating environmental base; the environment cannot be protected when growth leaves out of account the costs of environmental protection."

A rising level of economic development generates increased pollution, at least until a country reaches a GDP of about $5,000 per person, according to economists Gene Grossman and Alan Krueger (Figure 14-19). In the early stages of industrialization, pollution-control devices are an unpopular luxury that makes cars and other consumer goods more expensive. Consequently, twentieth-century environmental improvements in the MDCs of North America and Western Europe are likely to be offset by increased pollution in LDCs during the twenty-first century.

Critical to world pollution in the twenty-first century is China. The rapid economic transformation of China has resulted in rapidly rising levels of pollution. The country has 16 of the 20 most polluted cities, according to the World Bank. Wastewater discharge is increasing 2 percent per year, and most of it is not being treated. Air pollution is especially severe, because China depends heavily on burning coal to produce electricity, and even for home heat and cooking. Sulfur dioxide emissions from China are even crossing the Pacific Ocean and being deposited in the western United States. Chinese cars have not been subject to effective emission controls. The World Bank estimates that 10 percent of China's GDP is being lost to direct damage from pollution, including destruction of crops, medical bills, and sick leave payments.

The Brundtland Report was optimistic that environmental protection could be promoted at the same time as economic growth and social equity. By gradually changing development practices, economic growth and social equity can be made compatible with protecting the environment and conserving resources.

In recent years the World Bank and other international development agencies have embraced the concept of sustainable development. Planning for development involves consideration of many more environmental and social issues today than was the case in the past.

**Sustainability’s Critics**

Some environmentally oriented critics have argued that it is too late to discuss sustainability. The World Wildlife Fund (WWF), for example, claims that the world surpassed its sustainable level around 1980.

The WWF Living Planet Report reaches its pessimistic conclusion by comparing the amount of land that humans are currently using with the amount of "biologically productive" land on Earth. "Biologically productive land" is defined as the amount of land required to produce the resources currently consumed and handle the wastes currently generated by the world's 6-plus billion people at current levels of technology.

The WWF calculates that humans are currently using about 13 billion hectares of Earth's land area, including 3 billion hectares for cropland, 2 billion for forest, 7 billion for energy, and 1 billion for fishing, grazing, and built-up areas. However, according to the WWF, Earth has only 11.4 billion hectares of biologically productive land, so humans are already using all of the productive land and none is left for future growth.

Others criticize sustainability from the opposite perspective: human activities have not exceeded Earth's capacity, because resource availability has no maximum. Earth's resources have no absolute limit, because the definition of resources changes drastically and unpredictably over time. Environmental improvements can be achieved through careful assessment of the outer limits of Earth's capacity.

Critics and defenders of sustainable development agree that one important recommendation of the UN report has not been implemented—increased international cooperation to reduce the gap between more developed and less developed countries. Only if resources are distributed in a more equitable manner can LDCs reduce the gap with MDCs in level of development.

**Biodiversity**

Biological diversity, or biodiversity for short, refers to the variety of species across Earth as a whole or in a specific place. Biodiversity is an important development concept because it is a way of summing the total value of Earth's resources available for human use. Sustainable development is promoted when biodiversity of a particular place or Earth as a whole is protected.
Biological and Geographic Biodiversity

Species variety can be understood from several perspectives. Geographers are especially concerned with biogeographic diversity, whereas biologists are especially concerned with genetic diversity. For biologists, biodiversity refers particularly to the maintenance of genetic diversity within populations of plants and animals. Genetic diversity embraces species variation in genetic material, such as genes and chromosomes.

Scientists have classified about 2.5 million species, including 900,000 insects, 41,000 vertebrates, and 250,000 plants, and more than a million invertebrates, fungi, algae, and microorganisms. About 1.4 million species have been given names. Estimates of Earth's total number of species range from 3 to 100 million, with 10 million as a median "guess," meaning that humans have not yet "discovered," classified, and named most of Earth's species.

New species are constantly being identified—for example, three new bird species are found annually—but human actions are exterminating species more rapidly than they are "discovering" new ones. Human actions are responsible for the extinctions by destroying habitats, primarily through pollution of air and water, removal of existing plants and animals, and introduction of foreign or exotic species.

For geographers, biodiversity is measurement of the number of species within a specific region or habitat. A community containing a large number of species is said to be species-rich, whereas an area with few species is species-poor.

Two communities may have the same number of species and the same total population of individuals, yet one may be more diverse than the other, depending on the distribution of the total population among the various species. A community with a large population of many species is regarded as more diverse than a community that contains a preponderance of one species and a very small number of all of the others.

Strategies to protect genetic diversity have been established on a global scale. Some endangered species have been protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Examples include the curtailing of logging, whaling, and taking of porpoises in tuna seines (nets).

Strategies to protect biogeographic diversity vary among countries. Luxembourg protects 44 percent of its land and Ecuador 38 percent, whereas Cambodia, Iraq, and some former Soviet Union republics have no land under conservation.

Frustrated by the inability to precisely measure environmental impacts, Millennium Ecosystem Assessment has undertaken a multiyear effort to establish systematic data sets. Heavy reliance is placed on remote sensing and satellite mapping to establish data sets, such as in Namibia where satellite imagery is used to count and map the distribution of elephants, and in Mali where farmers receive satellite updates about storms on hand-wound radios.

Biodiversity in the Tropics

Reduction of biodiversity through species extinction is especially important in tropical forests. Three species per hour are extinguished in the tropics, and more than 5,000 species are considered in danger of extinction.

Tropical forests occupy only 7 percent of Earth's land area but contain more than one-half of the world's species, including two-thirds of vascular plant species and one-third of avian species. The characteristics of the tropical forest biome contribute to the presence of more species than in temperate or polar biomes. Higher temperatures, greater climate predictability, and longer growing seasons all create a more inviting habitat for a greater diversity of species.

At a small scale, a single stand of 19 trees in Panama examined in 1980 yielded 1,200 beetle species, 80 percent previously unknown. One gram of tropical soil can hold 90 million bacteria and other microbes.

The principal cause of the high rate of extinction is cutting down forests. Rapid deforestation results from changing economic activities in the tropics, especially a decline in shifting cultivation (see Chapter 10). Under shifting cultivation, a small portion of the forest is cleared to plant for a couple of years then left to regenerate over a couple of decades. Shifting cultivation is being replaced by logging, cattle ranching, and cultivation of cash crops. These alternatives require cutting down vast expanses of forest.

Governments in less developed countries support the destruction of rain forests, because they view activities such as selling timber to builders or raising cattle for fast-food restaurants as more effective strategies for promoting economic development than shifting cultivation. Until recently, the World Bank has provided loans to finance development proposals that require clearing forests. Shifting cultivation is also regarded as a relatively inefficient approach to growing food in a hungry world. The problem with shifting cultivation compared to other forms of agriculture is that it can support only a low level of population in an area without causing environmental damage.

Tropical rain forests are disappearing at the rate of 10 to 20 million hectares (25 to 50 million acres) per year. The amount of Earth's surface allocated to tropical rain forests has been reduced to less than one-half of its original area during the past quarter century, and unless drastic measures are taken, the area will be reduced by another one-fifth within a decade. Only 6 percent of Earth's forests are protected, leaving the remaining 33 million square kilometers (13 million square miles) vulnerable.

SUMMARY

We have examined problems of depletion and degradation of Earth's resources. The distribution of resources, as well as patterns of use and abuse, varies locally. But actions with regard to resources in one region can affect people everywhere.

Some scientists believe that further depletion and destruction of Earth's resources will lead to disaster in the near future. In 1968, a group of scientists known as the Club of Rome presented a particularly influential statement of this position in a report titled The Limits to Growth. According to these scientists, many of whom were professors at the Massachusetts Institute of Technology, the combination of population growth, resource depletion, and unrestricted use of industrial technology will disrupt the world's ecology and
economy and lead to mass starvation, widespread suffering, and destruction of the physical environment.

In a recent update, the authors argued that environmental destruction is proceeding at a more rapid rate than they had originally thought. If new sets of attitudes and policies toward environmental protection are not in place within 20 years, the environment will be permanently damaged, and people’s standards of living will fall.

The threat of irreparable global environmental damage is heightened by confrontation between more developed and less developed regions. The MDCs have achieved wealth in part by using large percentages of the world’s resources and discharging large percentages of the world’s pollutants. Now LDCs are being asked to promote economic development with greater sensitivity to the environment than today’s MDCs showed in the past. People in MDCs are increasingly willing to allocate some of their wealth to clean up the environment. Subsistence farmers in LDCs cannot afford to invest in environmental protection.

Most geographers recognize that unrestricted industrial and demographic growth will have negative consequences, but they do not believe that the dire predictions of The Limits to Growth are inevitable. Human actions have depleted some resources, but substitutes may be available. Although pollution degrades the physical environment, industrial growth can be compatible with environmental protection.

Demand for food is increasing, but human actions are also expanding the capacity of Earth to provide food.

Here again are the key issues in Chapter 14:

1. **Why are resources being depleted?** As we consume resources, we are depleting Earth’s supply. Fossil fuels and minerals are distributed unevenly across Earth, and supplies are not found in places where demand is highest.

2. **Why are resources being polluted?** Human beings are damaging and destroying Earth’s resources through pollution. Pollution is the discharge of waste at a rate that exceeds the environment’s capacity to absorb it. Pollutants are discharged into the atmosphere, water, and onto land.

3. **Why are resources reusable?** Depletion and destruction of scarce resources can be minimized by converting from nonrenewable to renewable sources of energy and by recycling more unwanted waste.

4. **Why can resources be conserved?** Sustainable development promotes economic development while not reducing the world’s current resource base. Especially important in conserving natural resources is to maintain biodiversity through minimizing species extinction in the development process.

---

**CASE STUDY REVISITED**

**Future Directions**

Mexico City has taken steps to reduce air pollution. The government closed a major employer, the PEMEX oil refinery, located in the northwestern region of Mexico City, because it was responsible for 7 percent of the city’s air pollution. Cars have been banned from a 50-square-block central area, and motorists are not allowed to use their cars one day each week, depending on the last digit of the license plate. Cars must now have catalytic converters and use unleaded fuel, and older buses and taxicabs have been removed from service.

However, Mexico must pay a price for implementing these pollution controls. Closing the oil refinery hurt Mexico’s economy, because not only were jobs lost but the country also had to import some fuel to replace the loss of the refinery’s production. Motor vehicles are essential to economic development, because they allow people to get to work and businesses to deliver goods. And the number of vehicles in Mexico City has expanded because of the rapid population growth.

Rapid population growth means that rapidly growing cities in LDCs face pressure to expand economic opportunities and material benefits for the people, regardless of environmental impact. Stricter enforcement of pollution controls would require shutting down many businesses and eliminating jobs.

Geographers emphasize that each resource in the physical environment has a distinctive capacity for accommodating human activities. Just as a good farmer knows how many animals can be fed on a parcel of land, a scientist can pinpoint the constraints that resources place on population density or economic development in a particular region. With knowledge of these constraints, we will be able to maintain agricultural and industrial development in the future.

A generation ago environmentalists coined the phrase “Think global, act local” so that we would recognize that our actions in our own communities—and even in our own backyards—could affect the entire planet. Now geographers urge us to “think global and think local.” In an age of globalization, we cannot lose sight of the importance and pleasure of the diversity of local physical conditions and human behavior. Think both global and local, and act wherever you can to do some good.

---

**KEY TERMS**

- Acid deposition (p. 483)
- Acid precipitation (p. 483)
- Active solar energy systems (p. 491)
- Air pollution (p. 481)
- Animate power (p. 467)
- Biochemical oxygen demand (BOD) (p. 485)
- Biodiversity (p. 496)
- Biomass fuel (p. 467)
- Breeder reactor (p. 477)
- Chlorofluorocarbon (CFC) (p. 482)
- Conservation (p. 495)
- Ferrous (p. 479)
- Fission (p. 475)
- Fossil fuel (p. 468)
- Fusion (p. 490)
- Geothermal energy (p. 490)
- Greenhouse effect (p. 481)
- Hydroelectric power (p. 489)
Inanimate power (p. 467)
Nonferrous (p. 479)
Nonrenewable energy (p. 468)
Ozone (p. 482)
Passive solar energy systems (p. 491)
Photochemical smog (p. 484)
Photovoltaic cell (p. 491)
Pollution (p. 480)
Potential reserve (p. 468)
Preservation (p. 495)
Proven reserve (p. 468)
Radioactive waste (p. 475)
Recycling (p. 492)
Renewable energy (p. 468)
Resource (p. 466)
Sanitary landfill (p. 487)
Sustainable development (p. 495)

THINKING GEOGRAPHICALLY

1. What steps has your community taken to recycle solid waste and to conserve energy?
2. U.S. automakers must meet a standard for Corporate Average Fuel Efficiency (CAFE). This means that the average miles per gallon achieved by all models of a company’s American-made cars must meet a government-mandated level. If they do not, the company must pay a stiff fine. Should the United States raise the CAFE standard to conserve fuel and reduce air pollution, even if the result is a loss of American jobs? Explain.
3. A recent study compared paper and polystyrene foam drinking cups. Conventional wisdom is that foam cups are bad for the environment, because they are made from petroleum and do not degrade in landfills. However, the manufacture of a paper cup consumes 36 times as much electricity and generates 580 times as much wastewater. Further, as they degrade in landfills, paper cups release methane gas, a contributor to the greenhouse effect. Which types of cups should companies such as McDonald’s be encouraged to use? Why?
4. Pollution is a by-product of producing almost anything. How can MDCs, which historically have been responsible for generating the most pollution, encourage LDCs to seek to minimize the adverse effects of pollution as they improve their levels of development?
5. Malthus argued 200 years ago that overpopulation was inevitable, because population increased geometrically while food supply increased arithmetically. Was Malthus correct? Why or why not?

FURTHER READINGS