following the 1973 energy crisis induced companies 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, most of which was discharged through the exhaust pipe, contributing to air pollution. To reduce the generation of lead—once a significant waste—carmakers 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. The amount of pollution generated by motor vehicles declined in 2008 and 2009 compared to earlier years primarily because consumers drove less during the severe recession.

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.

INCREASING ENVIRONMENTAL CAPACITY. The second way to handle pollution is to increase the capacity of the environment 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 wastewater 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. Industries 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 capacity 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 pollution, wet scrubbers are installed to wash particulates from the gas before it is released to the atmosphere. These 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.

Comparing Pollution Reduction Strategies

Relying on an increase in the capacity of the environment to accept discharges is risky (Figure 14-32). Because we do not always know the environment's capacity to assimilate a particular waste, we are likely to exceed it at times.

Dispersed wastes may remain harmful. A pollutant like sulfur dioxide might exist at tolerable levels in the air, but it damages trees when it accumulates in the soil. Recent history is filled with examples of wastes discharged into the environment in the belief that they would be dispersed or isolated safely—CFCs in the stratosphere, garbage offshore, and toxic chemicals beneath Love Canal. Many pollutants are mobile. They often travel from air to soil, or soil to water. Tall smokestacks built to reduce sulfur dioxide discharges around coal-burning industries and metal smelters were successful at dispersing sulfur over a larger area. But the result of the dispersal was that acid precipitation (containing sulfur) fell hundreds of kilometers away, polluting vegetation and lakes over a wide area.

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 Should 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. ■

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.

Conservation, Preservation, and Sustainability

Conservation is the sustainable use and management of natural resources such as wildlife, water, air, and Earth's resources

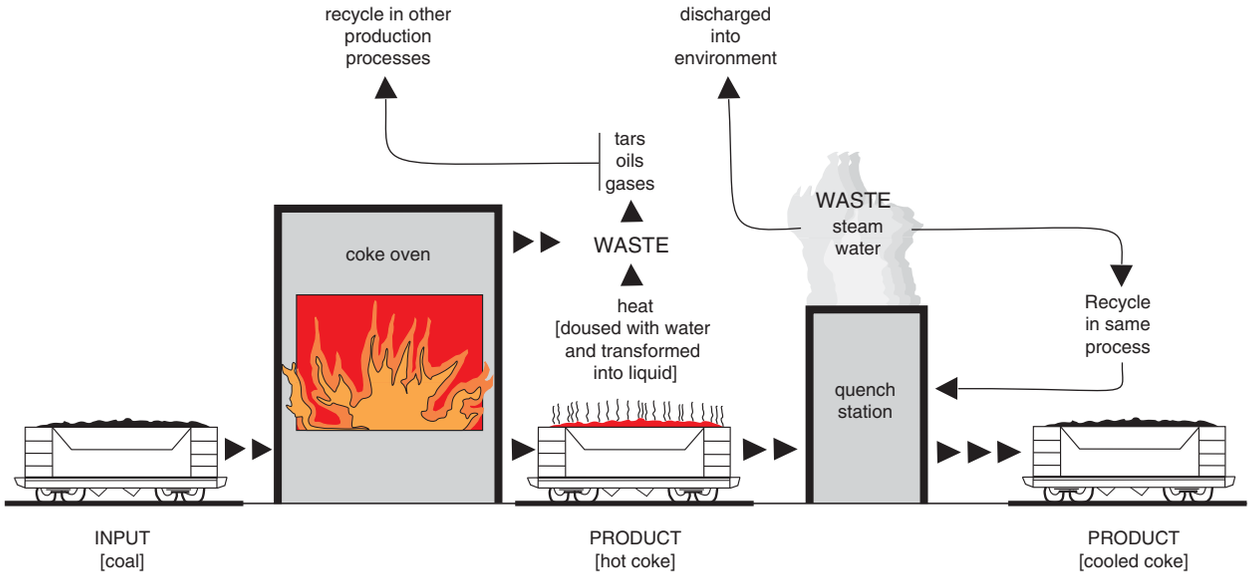

FIGURE 14-32 Comparing pollution reduction strategies. A coking plant, used for steelmaking, illustrates the application of principal alternatives for reducing pollution. The main input into a coking plant is a mixture of coal types, and the intended product is coke, which becomes an input in steel production. The coal is placed in a coke oven 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 pollution. 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 residual (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 discharges. 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 coke oven (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.

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 the maintenance of resources in their present condition, with as little human impact as possible. Preservation takes the view that 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.

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.

Sustainability and Economic Growth

The UN's "sustainable development" definition originated 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 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 (Figure 14-33). Plans to protect the environment will fail unless LDCs promote economic growth in a way that meets basic needs of employment, food, and energy, as well as 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 14-34). 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.

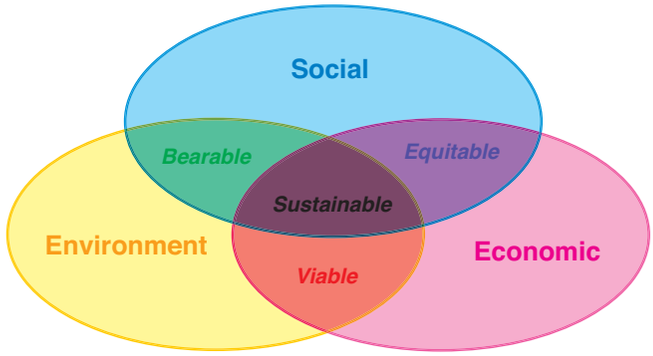

FIGURE 14-33 Sustainable development. Environmental improvement takes into consideration social and economic factors.

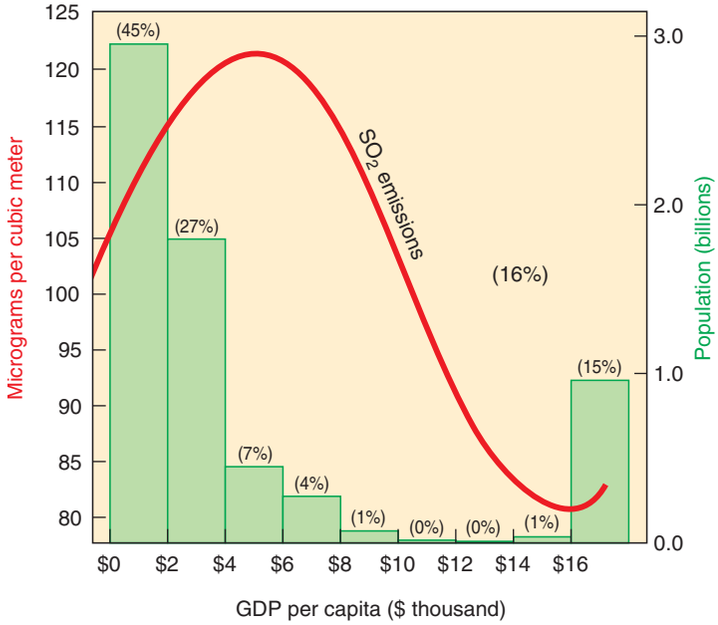

FIGURE 14-34 Pollution compared to a country's wealth. As a country's GDP per capita increases, discharge of sulfur dioxide increases, until GDP reaches about $5,000. Then, discharges tend to decrease as a country begins to spend money on pollution-control devices. The green bars show the percentage of people in each GDP per capita group.

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 as well as home heat and cooking. Chinese cars have not been subject to effective emission controls. Sulfur dioxide emissions from China are even crossing the Pacific Ocean and being deposited in the western United States. 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 the consideration of many more environmental and social issues today than was the case in the past. 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, for example, or the number of fish removed from a body of water can be controlled at a level that does not reduce future supplies.

Sustainability's Critics

Some environmentally oriented critics have argued that it is too late to discuss sustainability. One critic, the World Wildlife Fund (WWF), 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 7 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, they argue, because resource availability has no maximum, and 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 development gap with MDCs.

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 the 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, the United Nations created the Millennium Ecosystem Assessment to establish systematic data sets. Heavy reliance is placed on remote sensing and satellite mapping to establish these 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

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. Thus reduction of biodiversity through species extinction is especially important in tropical forests, where six species per hour are extinguished and more than 5,000 species are considered in danger of extinction. Although tropical forests occupy only 6 percent of Earth's land area, they contain more than one-half of the world's species, including two-thirds of vascular plant species and one-third of avian 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.

Tropical rain forests are disappearing at the rate of 10 to 20 million hectares (25 to 50 million acres) per year. Since 1950, the area of Earth's surface allocated to tropical rain forests has been reduced by more than half, and unless drastic measures are taken, the last rain forest will disappear around 2050. Only 6 percent of Earth's rainforests are protected, leaving the remaining 33 million square kilometers (13 million square miles) vulnerable.

The principal cause of the high rate of extinction is the cutting down of forests, which is the result of 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, which require cutting down vast expanses of forest. Governments in LDCs 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. Shifting cultivation is also regarded as a relatively inefficient approach to growing food in a hungry world; compared to other forms of agriculture it can support only a low level of population in an area without causing environmental damage. Until recently, the World Bank has provided loans to finance development proposals that required clearing forests.

SUMMARY

We have examined the 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*