This book presents a systems approach to environmental protection. One of its goals is to show how principles of sustainability derived from the study of ecology and other areas can be used to restructure human systems such as energy, transportation, waste management, and housing to protect the natural systems that support our
lives and to ensure a long, prosperous human presence. Chapter 2 made the case for this new approach to environmental protection. (If you haven't read them, you may want to do so now.)

This book also presents many ideas on ways to create nature-compatible designs to permit humans to thrive within the limits of the natural world. These new designs could allow human civilization to prosper without disrupting nutrient cycles, climate, wildlife, and natural environments. In fact, they could even enhance the environment, our life support system, and the source of all human wealth.

Table 17-1 lists the human systems that were discussed in Chapter 2. In Part IV, the chapters reviewed natural resource issues and solutions, highlighting ways to restructure systems such as energy, water supply, and agriculture to resolve resource issues based on the operating principles of sustainability. Although restructuring human systems and the global economy are essential to protect the environment and build a sustainable future, the task will not be easy, inexpensive, or quickly executed. The chapter you are about to read presents some additional ideas on sustainable systems. It addresses land use and transportation.

### 17.1 Cities and Towns as Networks of Systems

Think of the city or town you live in. It consists of people and the built environment—streets, shopping centers, office buildings, and schools. Look a little harder, though, and you will see the city or town as a network of interdependent human systems. There's a transportation system, consisting of roads and highways, gas stations, automobiles, buses, trucks, and airports. There's an energy system, consisting of gas stations, power plants, underground pipes that carry natural gas, and power lines that transmit electricity. There's most likely an elaborate system of water supply, consisting of deep wells or dams and reservoirs, water treatment plants, and an extensive set of pipes under the streets to transport water to homes, factories, businesses, schools, government offices, car washes, and parks. There's a waste management system as well. It consists of thousands of generators of waste—homes, factories, office buildings, and copy shops that produce millions of tons of waste each year. It also consists of ways to deal with waste, such as recycling centers, waste-to-energy plants that burn garbage, landfills in which waste is buried, sewage treatment plants, and hazardous waste facilities.

These networks of systems are designed to meet our needs for raw materials, finished goods, and services. They also get rid of the mountains of waste produced by human society. Some futurists believe that making cities sustainable will require a restructuring of these systems. Virtually every aspect of city or town life will need to be rethought and redesigned, although not everyone agrees that this is necessary or, if they do, about how this should be accomplished.

#### Table 17-1

<table>
<thead>
<tr>
<th>Human Systems</th>
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<tbody>
<tr>
<td>Energy</td>
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<tr>
<td>Transportation</td>
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<td>Waste management</td>
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<td>Water</td>
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<td>Industry</td>
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<td>Agriculture</td>
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### The Invisibility of Human Systems

Although there has been a lot of progress in the last four decades in environmental protection, many problems are worsening. As pointed out earlier, the vast majority of the trends are leading us away from a sustainable existence. It may be hard for people to accept the assertion that human
FIGURE 17-1 The kitchen is more than a place to cook.
The kitchen is an integral part of several key systems. Can you name them? How do natural systems support the human systems?

Society and the systems it depends on are unsustainable. Throughout this book you have seen many statistics that support this conclusion. As has been pointed out in previous chapters, pollution, species extinction, global warming, and a host of other environmental problems aren’t mere surface wounds that can be fixed with Band-Aids; they’re symptoms of deeper problems, most notably overpopulation and unsustainable human systems.

Why is it hard to grasp the problem with human systems? For much of the past 60 years, environmentalists, policymakers, teachers, and researchers have focused most of their attention on solutions that address the symptoms of the environmental crisis. Very little attention has been focused on human systems and their fundamental unsustainability. The basic assumption has been that if we solve the immediate problems, we’ll be all right. A little change here and there will cut pollution and reduce the negative effects on people and other living creatures.

Another important factor is that for most people systems are invisible. That is, they were designed to operate with minimal bother to us (FIGURE 17-1). The fact that we don’t think about systems very much is a tribute to the engineers who designed them. In fact, it’s generally only when a system breaks down that we notice it exists.

We turn on a light switch, and electricity surges through the wires. We turn on the faucet, and out comes drinkable water. We go to the grocery store, and the shelves are packed with food. We pull up to the gas station, and there’s plenty of fuel. We’re aware of light switches, faucets, and gas pumps, but we’re fairly ignorant about the rest of the systems. If we barely recognize their existence, how can we be concerned about them?

KEY CONCEPTS
Performance Versus Sustainability: Understanding a Crucial Difference
Another obstacle in the way of understanding the premise that human systems are unsustainable has to do with the distinction between performance and endurance. For most of us, the systems work well. The important distinction here is that just because a system is supplying us with the services we need doesn’t mean that it is sustainable. For example, just because the world’s fishing fleet is producing over 90 million tons of fish each year does not mean that this amount is a sustainable harvest level. In fact, this level of fish catch is severely depleting key fisheries, and we are headed for major shortages in the near future. The same is true with virtually all human systems.

KEY CONCEPTS
Why Are Human Systems Unsustainable?
Although it is difficult to determine the carrying capacity of the planet—that is, how many people it can support—it is easy to find evidence that we are exceeding it. Global warming, species extinction, land devastation, soil erosion, desertification, food shortages, and other problems are signs that we are exceeding the capacity of the Earth to support human life—and other life-forms as well.

These problems are partly a result of the massive size of the world population, but also a result of the design of the systems that support our lives. A system of energy based on efficiency and clean, renewable sources, for example, would have a fraction of the environmental impact of the present system (Chapters 14 and 15). A system of agriculture based on minimum tillage, crop rotation, soil conservation measures, and natural pesticides would be able to feed the
world’s people with much less impact on water, wildlife, and soils. Both could endure for many centuries, too.

The present systems are unsustainable because they produce waste and pollution in excess of the Earth’s capacity to absorb them. They end up poisoning us and other species. They change the climate. They adversely change the chemistry of rainfall. They’ve contributed to the present depletion of the ozone layer. They deplete both renewable and nonrenewable resources upon which our future depend.

Why do they do all of these things? As noted in Chapter 3, most systems are inefficient. They do not recycle or use recycled materials. They depend primarily on nonrenewable energy. They destroy but do not restore.

**KEY CONCEPTS**

Human systems are unsustainable because they exceed the carrying capacity of the Earth. They produce pollution in excess of the planet’s ability to absorb it, use renewable resources faster than they can be replenished, and deplete nonrenewable resources.

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### The Challenge of Creating Sustainable Cities and Towns

Cities and towns are a lot like the bird colonies that dot the rocky coastlines of many continents (FIGURE 17-2). Bird colonies are nesting and resting sites where large numbers of birds of the same species aggregate. They are also sites of enormous waste production and enormous food consumption—just like cities. But food for the colony and the city does not come from the immediate vicinity. It comes from neighboring ecosystems.

To be sustainable, cities and towns must have a lasting supply of resources. Proper resource management is therefore essential to the survival and sustainability of this pattern of habitation. Many changes can also be made in cities to ensure their sustainability. These changes are all designed to lessen resource demand and waste production while ensuring we meet our needs.

The challenge facing humankind is twofold. First, we must revamp existing infrastructure. Second, we must build new infrastructure in a sustainable fashion. Consider the task of revamping existing infrastructure first—the so-called redevelopment strategy.

One of the first steps in reducing resource demand and pollution is to make all buildings much more efficient in their use of energy—electricity, fuel oil, and natural gas (Chapter 15). We can make buildings much more efficient by sealing air leaks in the walls, adding insulation, and by replacing worn-out heating systems with newer, more efficient ones. We can also find ways to increase their dependence on renewable energy. For example, we can add photovoltaic systems to generate electricity or add solar hot water panels for domestic hot water and space heating (FIGURE 17-3). We can add low-flush toilets and water-efficient showerheads, faucets, and appliances to reduce resource demand. We can use recycled paint or low-toxicity paints. The list goes on.

Similar actions must be taken in transportation, housing, agriculture, waste management, and other systems—and are detailed in this book. Especially important are efforts to reduce urban sprawl, the continual expansion of human communities into farmlands and wildlands that provide vital resources required for our long-term economic health.

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**GO GREEN**

Recycling saves energy and resources. Recycle everything you can. Buy recycled goods, like recycled paper, too.

**GO GREEN**

To save water and energy and reduce pollution, take shorter showers.

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**FIGURE 17-2 Colonies and cities.** (a) Bird colony. (b) City. Cities resemble bird colonies in many ways. They are areas of intense activity where resources from outlying areas are consumed. They are also areas of concentrated waste production.
and survival. This topic is discussed in Spotlight on Sustain-
able Development 9-1 and in Chapter 10 on agriculture and
Chapter 11 on preserving biological diversity.

Redevelopment is a vital but often overlooked strategy
for sustainable development, in large part because so much
infrastructure is already in place and because billions and bil-
lions of dollars have been invested in it. It is imperative that
we make this infrastructure as sustainable as possible. Tens
of millions of single-family homes and apartment buildings
and millions of businesses are currently in use and are prime
targets for sustainable redevelopment.

The second challenge—designing and building new in-
frastucture to be as sustainable as possible—takes place
when systems need replacement or require expansion. To
expand a transportation system in an urban environment, for
example, cities can install light rail systems rather than
adding new lanes to existing highways. New housing could
be constructed from recycled products and would be
equipped with a host of resource-saving devices so that new
houses use only a quarter of the raw materials of existing
houses. Rather than adding a landfill, a city could expand its
recycling facilities to handle waste.

Specifics of these two prescribed actions are outlined
in chapters on energy, waste, water, forestry, mining, and air
pollution. The reader should refer to those chapters for
specifics. In this chapter, we look primarily at land-use plan-
ning and transportation, which are not covered elsewhere.

**KEY CONCEPTS**

Two challenges face existing communities: revamping existing
infrastructure and building new infrastructure in as sustainable
a manner as possible.

### 17.2 Land-Use Planning
and Sustainability

A city or town is home to many different activities, some
that conflict with one another: for example, housing and
factories. For many years, cities and towns the world over
have engaged in land-use planning to ensure that incompat-
able activities are kept apart. Land-use plans, for example, set
up industrial zones and residential zones. Besides determin-
ing where people can live and do business, land-use plans es-

dablish sites for water pipes, electrical lines, roads, and
shopping malls. In some countries, land-use planning has
been fashioned in a way to prevent or reduce sprawl.

**KEY CONCEPTS**

Land-use planning helps cities establish the locations of vari-
ous structures and activities and keep incompatible uses apart.
As conceived and practiced in most places, it doesn’t do much
for sustainability.

### Sustainable Land-Use Planning:
Ending Sprawl

Sustainable land-use planning seeks to accomplish the same
goals as land-use planning, notably separating humans from
unsightly, noisy, and potentially dangerous activities. But it
also attempts to achieve more efficient use of the land—in
other words, to create patterns of land use that minimize the
conversion of farmland and wildlands to asphalt, concrete,
and lawn. That is, it strives to prevent or control sprawl. This
helps to preserve farmland, recreational areas, wetlands, sce-
nic views, watersheds, aquifer recharge zones, and wildlife
habitat—retaining aesthetic values and ecological services. The
rationale for saving these lands has been discussed in Chap-
ters 9 through 11.

Sustainable land-use planning also entails efforts to co-
ordinate key uses such as housing, business, and transporta-
tion development. Ultimately, land-use planning seeks the
best for people, the economy, and the environment. It can in
fact improve economies by reducing the loss of productive
farmlands, by reducing air pollution and costly health prob-
blems, and by making the provision of government services
such as police and fire protection more efficient. It can, there-
fore, create more efficient government.

**FIGURE 17-4** shows four major types of development:
dispersed, compact, satellite, and corridor. Let’s examine
each one very briefly and assess its potential for promoting
sustainable development.

**KEY CONCEPTS**

Sustainable land-use planning and development seek to optimize
land use and minimize the loss of economically and ecologically
important lands. They offer other benefits as well, including more
efficient mass transit, reduced air pollution, and reductions in
the cost of providing water, sewage, and other services.

**Dispersed Development** Dispersed development occurs
in many cities and is commonly referred to as urban sprawl.
Urban sprawl is the steady outward expansion of urban/suburban areas that occurs as new housing subdivisions, highways, shopping malls, and other forms of development spring up on the perimeter of existing cities and towns, taking over farmland, forest, and grassland (Figure 17-4a).

In many cities, land is already zoned for this type of development. Dispersed development, however, ranks low on the sustainability scale. In fact, it is the least desirable of all of the alternatives because it consumes lots of land. Farmland, forests, wetlands, and grasslands are all victims of sprawl. Because cities are often located near prime farmland, sprawl decreases a nation’s long-term ability to produce food (Chapter 10) and displaces wildlife (Chapter 11). Loss of natural habitat and replacement with paved surfaces often increases flooding (Chapter 12). Furthermore, sprawl results in a rather haphazard pattern of settlement, with poor aesthetic appeal.

Because housing spreads out inefficiently on the landscape, dispersed development increases vehicle travel, adding to commuting time and increasing energy consumption and air pollution. Each of these has a cost. Increased commuting time means more time away from families and friends and less free time. Increased energy consumption, caused by the need to travel farther to work each day, costs more in gas and wear and tear on the automobile. Air pollution takes its toll on people and the environment.

Sprawl has other costs. Providing highways, mass transit, sewers, water, and other forms of infrastructure generally costs more than the alternative forms of development because more miles of water and sewer lines, telephone lines, and power lines must be run to supply homes and businesses strewn out inefficiently across the landscape. Police and fire protection in a sprawling urban environment is often more costly.

GO GREEN
To save energy and reduce pollution, live close to where you go to school and work. Walk or ride a bike to work, if you can.

KEY CONCEPTS
Dispersed development or urban sprawl is the most environmentally and economically unsustainable form of urban/suburban development.

Compact Development Figure 17-4b shows an alternative development pattern, compact development. Ranking highest on the sustainability scale, compact development is a denser or more compact form of development. It requires
lying lands. In many U.S. cities, making compact development creates a clear line between city and suburb and the outlying lands. Amenities such as services like fire protection, water, sewers, and other expenses can be shared more efficiently if homes and businesses are placed closer together. Mass transit systems use much less energy and are far easier and more efficient to implement if people live closer together. As discussed in the next section, compact development not only minimizes land use, it decreases more pollution than compact development. It is, however, amenable to mass transit.

One promising development, which began in Denmark in the 1970s, is cohousing, a residential living arrangement that strives to create a community. Cohousing developments are small neighborhoods that offer many social and economic benefits, described in Spotlight on Sustainable Development 17-1.

In many cities and towns, businesses are strewn along highways in highly dispersed fashion. Aggregating services close to residences can cut down on driving time and make them accessible by foot or bicycle.

Compact development not only minimizes land use, it also reduces vehicle miles traveled and can substantially reduce energy consumption and air pollution. Perhaps more important, dense settlement patterns are much more amenable to mass transit systems, which, as discussed in the next section, are far easier and more efficient to implement if people live closer together. Mass transit systems use much less energy and require much less space to move people than automobiles do.

Proper land-use planning can also be carried out on a smaller scale—for example, the development of a subdivision. When applied to specific sites, land-use plans take into account the slope of the land, soil quality, water drainage, location of wildlife habitat, and many other features. This permits planners and developers to design with nature, rather than redesigning nature. In The Woodlands, Texas, for example, a developer placed the homes outside the natural drainage areas, saving millions of dollars that otherwise would have been required to construct storm sewers. This also left an attractive open space rich in wildlife that local residents enjoy.

KEY CONCEPTS

| Land-Use Planning and Building | Corridor and Satellite Development |� Corridor and Satellite Development are satellite development and corridor development. Satellite development, shown in Figure 17-4c, involves the development of outlying communities connected to the metropolitan area (the city and the surrounding suburbs) by highways and rail lines. Although this permits people to live outside the city and suburbs in small towns—and can create a very desirable quality of life—it is not as advantageous from many perspectives as compact development. It results in the conversion of a fair amount of open space and farmland. Although satellite development does not require as much land as dispersed development, it increases commuting time, energy consumption, and air pollution. Of the four options, it ranks number two in sustainability. Corridor development, concentrating housing and business growth along major transportation corridors, is even less desirable (Figure 17-4d). It requires much more vehicle use to get to work and to services. It uses more energy and produces more pollution than compact development. It is, however, amenable to mass transit. Clearly, of all of the options described in this section, compact development offers the best benefits and is the most sustainable form. When properly executed, land-use planning can help us achieve a more sustainable relationship with the Earth. Land-use plans can protect the foundation of tomorrow’s civilization: renewable resources such as farmland, pastures, forests, fisheries, and wild species.

KEY CONCEPTS

| | Compact development is a denser settlement pattern that offers many environmental benefits, such as reduced land use and air pollution and increased efficiency of mass transit. |
Many steps can be taken when building homes to protect valuable ecological assets. These can save developers money and reduce cost.

**SPOTLIGHT ON SUSTAINABLE DEVELOPMENT**

**17-1 Cohousing: Building a Community**

In the past, many people lived in villages or in tightly knit urban neighborhoods. Families were familiar with people’s past histories, their talents, and weaknesses. There was a sense of community that is often lacking in modern neighborhoods. Community provided a sense of belonging, a sense of security. It was a more practical way to live, too. People helped each other, sharing the burden of everyday life.

In modern society, community has withered and died. Designers of modern suburbs where many of us live take special care to ensure privacy, rather than promote closeness. In many neighborhoods, for example, fences line our back yards, walling us off from contact with neighbors. In fact, few of us see our neighbors any more. If we do, it is usually just to glimpse them coming and going—driving in and out of the garage. At night, many people returning from work simply slip into the garage without a trace. Although people do socialize, it is often with friends who live far from their homes. Given the distance that separates us, many people complain that they have to make appointments to see their friends. No one just drops in to say hello. Because there isn’t much of a community in the neighborhoods we live in, many people begin to feel isolated. Life becomes a chore.

Disenfranchised with the lack of community in modern society, people throughout the world are banding together to recreate a sense of belonging through cohousing. **Cohousing** usually consists of houses or apartments clustered around a common area and a common house. Usually consisting of around 30 homes or apartment dwellings, cohousing is occupied by people who planned their “development” and now manage the community they’ve developed. Individuals own or rent their homes, but share in the ownership of the commons. They also share in some of the work. One person, for example, might lead a committee that plans social events. Another might organize weekend work projects. Still another might coordinate day care.

In cohousing, many resources are shared, too. For example, in Golden, Colorado, Harmony Village’s 27 families share a single lawn mower. The common house also offers a tremendous opportunity to share. In many common houses, there’s a shared laundry facility. Two washers often serve an entire community. A television room and places for kids to hang out, to play without disturbing adults, are features of many common houses. The common house also typically has a large kitchen where community meals are prepared, sometimes every night of the week. The preparation of community meals is a shared responsibility. Imagine coming home from work to have a meal on the table and only being responsible for cooking once or twice a month.

Because of the sharing of resources, individual units are typically downsized. Kitchens, for example, tend to be much smaller, more like those found in apartments. If you are planning a big meal for friends, you book the common house and use the larger kitchen facility.

The common house may also have a room or two for guests, so you don’t need a spare bedroom for that once-a-year visit by mom and dad. Mechanic shops, greenhouses, gardens, and playgrounds are also shared by residents, greatly cutting down on expenses and reducing personal living space.

Common meals and activities help knit a community together. But the initial weaving of the social fabric comes during the development of the community. In most instances, a core group of people does the planning from day 1 and sees the project through. This involves numerous meetings and discussions to reach consensus. Although this is difficult at first, with practice, residents say it becomes much easier. In fact, many people claim that the skills they learned in cohousing benefit them in both their home and work lives.

**FIGURE 1** shows the layout of cohousing. As you can see, houses face a central area, a common area, where kids can play freely. Adults socialize in the commons, too. Cars are typically relegated to a peripheral position, usually garages, parking lots, or carpports along the outside of the community. Although the car is never more than a block or so away from your home, you generally can’t park next to your home, except perhaps to deliver groceries. The walkways are made...
market system, which, left on its own, appropriates land irrespective of its long-term ecological value.

Many European nations have adopted similar programs. In Belgium, France, the Netherlands, and the former West Germany, national guidelines for land-use planning were established in the 1960s. Administered by local governments, they protect farmland, prevent urban sprawl, and help to establish greenbelts, undeveloped areas in or around cities and towns (FIGURE 17-5). The Netherlands has one of the best programs of all. Its national planning program also governs water and energy use.

Land-use planning at the federal level in the United States is rudimentary at best. Except for establishing national parks, wilderness areas, national forests, and wildlife preserves, the federal government has done little to systematically protect its land. Most zoning occurs on the community level. On the local level, planners concern themselves primarily with restrictions on land use for commercial purposes—housing for people, not cars. As a result, cohousing is kid and pedestrian friendly.

The common house is usually in view of all the units in cohousing. It is the heart of the community. Some cohousers have organized day care in the common house so they can leave for work and not have to transport their children to another location, saving time and money.

Privacy is designed into all cohousing so that people can satisfy this need too. In many instances, private patios or gardens are located outside the back door. You’re not forced to socialize if you need alone time.

Cohousing is found in rural and urban settings. It is a great place for kids to grow up, and adults, too. It provides a rich social atmosphere.

Cohousing is not a new idea by any stretch of the imagination. It began in Denmark in the 1970s. The pioneers in cohousing sought to create a child-friendly atmosphere and opportunity to share some daily functions. Since that time, hundreds of new communities have sprung up in Europe, Canada, and the United States. Most are organized around the idea of community. However, a growing number of communities have been formed to create a more environmentally responsible way of living. In Nyland Cohousing in Lafayette, Colorado, the homes were designed and built to conserve energy and use solar energy for heating. Environmentally friendly building materials, were used, too. In Denmark, several cohousing developments have incorporated passive solar design and wind energy to generate electricity.

Cohousing is growing rapidly and is bound to increase in years to come. Being a more compact form of development, in which some space is often devoted to habitat preservation, cohousing is not only good for people, it is good for the planet.

GO GREEN
Take a break from your studies and visit a local cohousing community. You can find one near you by visiting the cohousing association web site.

FIGURE 17-5 An architectural sketch of the layout of a typical cohousing community.
developments and industrial development. Because of the United States' reliance on community-level planning, states are a patchwork quilt of conflicting rules and regulations. Some people believe that statewide land-use planning is needed. Statewide land-use planning is an idea that is slow in coming. Oregon passed such a program in the early 1970s, discussed in Spotlight on Sustainable Development 9-1. Noteworthy programs now exist in Maine, New Jersey, Florida, Vermont, Washington, and Hawaii.

KEY CONCEPTS

Beyond Zoning

The main tool of land-use planning for years has been zoning regulations, which classify land according to use. Zoning can protect farmland and other lands from urban development. In rural Black Hawk County in Iowa, for instance, zoning laws prohibit housing developments on prime farmland, but permit them on lands with lower productivity. New approaches are also being adopted to protect valuable land, especially farmland. One public policy tool is the differential tax rate. This allows city officials to tax different lands at different rates. Farmland is taxed at a lower rate than housing developments, making it more economical to farm—and encouraging farmers to hold onto their lands rather than sell them to developers. Another technique that helps farmers keep their land instead of selling it to developers is the purchase of development rights. A development right is a fee paid to a farmer to prevent the land from being “developed,” that is, being bulldozed, paved, and built on. To determine the cost of a development right, two assessments of the land are made, one of its value as farmland and one of its value for development. The difference between the two is the development right. State or local governments may buy the development rights from the farmer and hold them in perpetuity. From then on, the land must be used for farming, no matter how many times it changes hands.

Still another way to reduce the spread of human populations onto valuable land is by making growth pay its own way. This idea calls on developers and new businesses to pay the cost of new schools, highways, water lines, sewer lines, police protection, and other forms of infrastructure needed as communities expand. The rationale is that the cost of new development should be passed on to those who profit from it, not to existing residents. A new home thus comes with a development fee attached, which the new homeowner pays.

This not only keeps local taxes from rising to subsidize new development, it encourages builders to locate new housing projects closer to existing schools, water lines, and highways. This, in turn, reduces sprawl and reduces the destruction of farmland and other ecologically important sites. Development fees might also encourage developers to install water-efficient fixtures and pay for water efficiency measures in existing homes and businesses, thus preventing an increase in demand.

Open space—fields, forests, and other valuable lands—can also be purchased and set aside for wildlife or designed for mixed use—that is, as parks in which people and wildlife can coexist. Open space acquisition is practiced in many areas. In some counties, a small sales tax raises millions of dollars to purchase land. In others, real estate transfer fees (a tax paid when houses and land are bought and sold) are used to buy open space. Although these methods raise much money, open-space lands often command a premium price.

KEY CONCEPTS

Many states and nations have land-use planning that minimizes urban sprawl.

Land-Use Planning in the Less Developed Nations

Urban sprawl is a major problem in the less developed nations. In fact, millions of hectares of farmland are destroyed each year by expanding urban centers. Land-use planning is therefore as essential in the less developed countries as in the industrial nations.

In some areas, land reform is badly needed. Wealthy landowners in many Latin American countries, for example, graze their cattle in rich valleys while peasants scratch out a living on the erodible hillsides. Hilly terrain that should be protected from erosion is being torn up by plows and washed away by rainfall. Some argue that sensible land use hinges on reform of these outdated landholding systems.

These are just a handful of ideas that could help reshape government policy to foster sustainability. Combined with many other ideas given in previous chapters—to promote sustainable ethics, revamp economics, and reshape unsustainable systems—they could form a national framework for...
dramatically realigning human systems to steer us onto a sustainable course.

**KEY CONCEPTS**

Land-use planning and land reform are also essential to creating sustainable land-use patterns in the developing nations.

### 17.3 Shifting to a Sustainable Transportation System

In 1950, the global automobile fleet numbered only 50 million; in 1998, the number was 508 million. In 2010, it had climbed to around 750 million. Americans are among the most avid automobile users on the planet. Each year, Americans travel more than 4.16 trillion kilometers (2.6 trillion miles) in their automobiles—the equivalent of more than 13 round trips to the sun, 149 million kilometers (93 million miles) away.

In the United States, over 200 million automobiles are currently on the road. This impressive total results from a number of factors, among them inefficient land-use planning (that results in urban sprawl) and inadequate mass transit systems. Affluence and the expansive nature of the country also contribute to America’s having the highest per capita auto ownership on the planet. In the United States, automobile travel accounts for 90% of the motorized passenger transport. In Europe, where mass transit is much better developed and where cities are more compact, the auto still accounts for 78% of the passenger transport.

Air travel is another major component of modern transportation. World air travel has grown rapidly in the past five decades from 28 billion passenger kilometers per year to nearly 3720 billion today (FIGURE 17-6). Besides carrying people, jets also carry huge amounts of freight. Unfortunately, the rising demand for air travel comes at an increasingly high environmental cost. Aviation consumes at least 5% of the world’s oil each year. It is also the most polluting form of transport per kilometer traveled. According to the Worldwatch Institute, a single DC 10 flight from Los Angeles to Tokyo emits 266 tons of the greenhouse gas carbon dioxide. The Worldwatch Institute points out that aviation currently accounts for 3% of global human carbon dioxide emissions and 2% of global nitrogen dioxide emissions, but these figures could rise to 11% and 6%, respectively, by the year 2050 if global air travel continues to increase as projected.

Today, more than 30% of the energy Americans consume is used by the transportation sector, and much of that powers our automobiles and jet aircraft. But are automobiles and jets sustainable forms of transportation?

Many observers believe that the answer to this question is no. The planet cannot absorb the pollutants produced by them. As the number of cars and jets expands and as the number of miles traveled each year increases, air pollution is bound to worsen. Oil spills could increase as the amount of oil being shipped increases. Atmospheric carbon dioxide levels are bound to rise as the combustion of fossil fuels increases. Acid deposition and urban pollution, both caused in large part by pollutants in automobile exhaust, could expand and threaten the health of people and ecosystems. Urban congestion, already at headache levels in many cities, is bound to worsen. Declining oil supplies also make the automobile and jet aircraft unsustainable. Road construction and maintenance are also quite costly. And tens of thousands of people are killed and injured each year in automobile accidents just in the United States.

Clearly, even though they provide us with great joy and mobility and are an important aspect of our economy, automobiles come with a huge price tag. So do jets. What can be done to shift to a more sustainable transportation system? Will the automobile continue to play a predominant role? Will jet aircraft travel continue to rise? The shift to a sustainable system of transportation will very likely occur in phases.

**KEY CONCEPTS**

Automobiles are a major component of the global transportation system. Declining oil supplies, congestion in urban areas, regional air pollution problems, and global climate change are problems associated with their use that are likely to help stimulate a shift to a more sustainable transportation system.

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**Phase 1: The Move Toward Efficient Vehicles and Alternative Fuels**

The first step in the transition to a sustainable transportation system will be an improvement in efficiency; a change that has already begun. Improving fuel efficiency has several benefits essential to sustainability.

First, it helps stretch oil supplies, providing time for the development of sustainable fuels and sustainable modes of transportation. Second, it reduces air pollution. The more efficient a vehicle is, the less pollution it produces. Third, it reduces the need to drill for and transport oil. Important as they
are, efficiency gains could easily be offset by both the rising number of vehicles on the road and the increasing number of miles people are driving each year.

What is happening to fuel efficiency in the United States? In 1982, the average new American automobile got about 9 kilometers per liter of gasoline (22 miles per gallon). By 1992, the average fleet mileage had edged up to 11.9 kilometers per liter (about 28 mpg). But progress stagnated in the 1990s and 2000s because of heavy pressure on Congress from auto manufacturers interested in selling minivans, trucks, and sport-utility vehicles. Sales of these relatively inefficient, but highly popular vehicles, are more profitable than energy-efficient vehicles. Today, minivans, trucks, and sport-utility vehicles account for about two-thirds of all new car sales in the country. Because of this trend, in 2007, the average gas mileage of new vehicles in the United States fell to 19.8 mpg. Efforts to increase fuel economy have reversed the downward trend. In 2010, the average fuel economy for new vehicles was set at 27.5 mpg and thanks to the Obama administration will rise to 35.5 mpg by 2016.

Creating More Fuel-Efficient Cars and Better Highway Systems Improvements in gasoline mileage can be achieved by many different techniques that can be combined to produce safe, lightweight, and extremely efficient vehicles. Engine re-design, for instance, can improve fuel efficiency. Improvements in aerodynamics—how the air flows over a moving vehicle—can also improve efficiency, as can lightweight materials such as the new foams and plastics. Space-age materials and air bags can increase the safety of the smaller, more energy-efficient vehicles. The alleged dangers of smaller cars could also be mitigated by tougher drunk-driving laws, enforcement of speed limits, and better driver education.

California has been a catalyst for many of the changes occurring in automobile design. In 2004, the California Air Resources Board released a proposal for regulations that would decrease greenhouse gas emissions from autos by 1% to 2% statewide by 2009. The state was sued by a consortium of auto manufacturers, but their suit was rejected in court in 2007. In 2005, California’s Governor Schwarzenegger signed an executive order committing the state to reduce carbon dioxide emission by 25% by 2020 and 80% by 2050.

Some auto manufacturers have responded admirably to the challenge. In 1998, for example, Honda released a natural gas version of the Civic whose emissions are so clean they don’t register on emission test equipment. As noted in Chapter 15, hybrid cars are now being sold by many auto manufacturers, domestic and foreign. These vehicles have small gasoline-powered piston engines combined with electric motors, which are controlled by an on-board computer. In the Toyota Prius, the electric motors are used to power the vehicle at slow speeds (FIGURE 17-7). The gas engine is used for higher speeds. These new vehicles are getting around 40 to 50 miles per gallon, but further improvements could greatly increase the gasoline mileage.

Two promising developments are the plug-in hybrid and electric car, discussed in Chapter 15. Besides increasing efficiency of vehicles by improving engines and automobile aerodynamics, engineers are studying ways to change the way cars are driven. Imagine climbing into your car, punching your destination into the computer, and then sitting back to read the newspaper. This is the dream of some technologists who are working on cars that drive themselves. The experimental models are either equipped with on-board computers that sense the sides of the road and traffic and keep the car in its lane or sensors that pick up a signal from a wire embedded in the highway. One of the chief benefits of this strategy would be that traffic would move more smoothly and more efficiently, reducing commuting time and pollution.

Another innovation is the use of computers to unjam congestion. Currently, engineers are using computers to understand and eliminate some of the factors that cause traffic congestion. These analyses are also helping cities to design highways to reduce congestion. Better controlled traffic lights and electronic signs that provide information to drivers to guide them toward better choices could reduce commuting time and prevent congestion.

Creating More Efficient Aircraft Aircraft manufacturers have made significant strides in improving fuel efficiency. Concerns over the impact of aviation and desires to reduce...
costs have led manufacturers such as Boeing/McDonnell Douglas and General Electric to take measures to improve efficiency in jet engines. In large part because of their efforts, today's new jets use about half as much fuel as those manufactured in the mid-1970s. Aircraft manufacturers are continuing to improve the efficiency of their jets. Even with these advances, air travel is growing so quickly that other means may be needed to reduce environmental impacts.

**KEY CONCEPTS**

Aircraft manufacturers have made much more impressive strides in improving fuel efficiency.

**Alternative, Clean-Burning Fuels** Alternative fuels are also part of the immediate transition to a more sustainable system of transportation. Cars, trucks, and buses can be powered by a variety of fuels, including hydrogen and ethanol, an alcohol produced from renewable sources such as corn and wood. Besides being renewable, these fuels burn very cleanly. Interestingly, many new cars are now designed to operate on gasoline and a 85% ethanol–gasoline blend (called E-85). Known as flex fuel cars, they’re growing in popularity.

Mentioned previously, another technology that holds some promise is the electric vehicle. Electric vehicles are much cleaner than standard gasoline-powered engines.

Another technology for electric cars that some people think holds tremendous promise is the fuel cell, described in Chapter 15. This device produces electricity used to run electric motors in cars, home generators, and other applications. Fuel cells are powered by hydrogen that can be derived from renewable resources (such as water) and nonrenewable fuels (gasoline, natural gas, and methanol). Unfortunately, it takes energy to make hydrogen. It is three to four times more efficient to use that energy (electricity) to power an electric vehicle.

Yet another fuel that holds great promise is biodiesel. Derived from vegetable oil, biodiesel burns in conventional diesel engines and produces a fraction of the air pollution of a conventional oil-based diesel. Biodiesel was discussed in Chapter 15. Also covered in Chapter 15 is vegetable oil, a fuel that can be burned in diesel engines with only minor modifications. For more on green cars and green fuels, you may want to read one of my newest books, *Green Transportation Basics*, published by New Society Publishers in 2010.

**KEY CONCEPTS**

Alternative fuels that burn cleanly and are renewable could also help reduce many problems created by the gasoline-powered automobile.

**Phase 2: From Road and Airports to Rails, Buses, and Bicycles**

The shift to clean-burning cars is essential, but like improvements in efficiency, it may be only a stopgap measure. By the year 2010, there were about 500 cities in the world that contained over a million people, and more than 26 of these housed over 10 million people. As cities grow, large numbers of commuters will very likely have to shift to mass transit—buses, commuter trains, and light rail (single-car trains)—to reduce highway congestion.

For a case study on one city’s successful use of mass transit, see Spotlight on Sustainable Development 17-2.

Besides reducing highway congestion by taking cars off the road, mass transit is inherently more efficient than the automobiles. A diesel bus used to transport people, for instance, only gets 4 miles per gallon, but with 40 people on board the passenger miles per gallon of fuel increases to 160. Light rail, commuter trains typically run on electricity, perform well, too.

Another option is carpooling and vanpooling—encouraging people to ride together. Carpooling is much more efficient than driving alone. For instance, the average new car on the road today gets only about 27.5 miles per gallon. If there’s one person on board, that’s 27.5 passenger miles per gallon. With two people, it jumps to close to 55 passenger miles per gallon (considering the additional weight being carried). Although that’s an improvement it is not as efficient as light rail or bus transport. With three on board, it increases to nearly 83 passenger miles per gallon. If there are four passengers, it jumps to 110 passenger miles, still half that of the bus.

Given the relative efficiency of mass transit—and given declining fuel supplies, congestion, and pollution—many urban residents may within the next few decades give up their second and third automobiles. They will turn to more efficient and less polluting forms of transportation, among them commuter trains, light rail, and buses. Some mass transit users may even join car-share programs. Participants in commercial car-share programs lease cars by the hour for special trips but rely on mass transit for most of their daily trips. To learn more about car-sharing programs, see Spotlight on Sustainable Development 17-3.

The shift to mass transit is inevitable over the coming decades, but cities will have to improve their systems, making them much more rapid and convenient. With declining automobile traffic, cities may be able to convert highway lanes to light rail lines. Median strips could be converted to light rail systems serving surrounding suburbs. Fast, efficient buses could carry commuters from their homes to outlying rail stations, where people board high-speed trains that transport them rapidly to urban centers.

To be profitable, high-speed rail requires high-participation, high-density population in outlying areas, and a large central business district. In order to achieve this, it may be necessary to densify new suburbs—that is, to foster a more compact form of development, as described in the previous section.

Another idea gaining interest is in making new subdivisions more like small towns—that is, making them more...
Curitiba, Brazil—A City with a Sustainable Vision

Most modern cities have grown up around the automobile. City planners have literally shaped their cities around major transit corridors. Thus, the location of subdivisions, industrial facilities, and services has been largely determined by roads and highways, access routes primarily traveled by people in automobiles.

Proving that there is an alternative path is a city that’s gaining wide recognition: Curitiba, Brazil. Lying near the east coast in the southernmost part of Brazil about 800 kilometers (500 miles) south of Rio de Janeiro, Curitiba is a showcase of wise planning and sustainable design principles that have served the city and the planet well.

Since 1950, Curitiba’s population has grown from 300,000 to over 2.1 million. For most cities, this rate of growth, combined with poor planning, would have been a prescription for disaster. Poverty, pollution, crime, and highway congestion would have been the inevitable results—not so in Curitiba.

The city was blessed with a visionary mayor in the 1970s, Jaime Lerner, who adopted proposals first made in the 1960s to plot a future for the city based on mass transit, ecological design, appropriate technology, and public participation—all essential elements of sustainability. Lerner was an architect and planner of extraordinary vision.

As witness to his foresight, consider this: Today, 1.3 million commuters travel into Curitiba each day to go to work. Three-quarters of these people travel by bus. This remarkable feat is made possible by an extensive, privately operated bus system that transports people in and out of the city with remarkable speed.

In most cities, bus systems are notoriously slow. Although they move large numbers of people, they bog down in heavy traffic on city streets. In Curitiba, however, buses move passengers into and out of the city at such rapid speeds for several reasons. First, the city has constructed five major roadways that penetrate into the heart of the city. Each of these roadways has two lanes designated for buses. In addition, bus stops are equipped with special devices called raised tubes, which allow passengers to pay before they get on the bus (FIGURE 1). This greatly speeds up the boarding process that slows down many a bus in the United States and other countries. Extra-wide doors also contribute to the speed of boarding. Double- and triple-length buses increase the system’s capacity. Together, these innovations reduce the transit time by one-third.

Curitiba has made it possible to move in other directions as well. Many smaller bus routes connect residential areas with the main transit corridors so that one can travel about freely. Commuters can take a bus to the main route, hop on an express bus, and be downtown in record speed.

This system of transit not only makes good sense from an environmental standpoint—because buses transport people with fewer resources and much less pollution than the automobile—it also makes sense from an economic standpoint. It’s much cheaper than a subway system.

So that the less fortunate, Curitiba’s poor, can gain access to the system, the city purchased land along major corridors, which was developed for low-income families.

Curitiba has more to boast about than its mass transit system. It has established an extensive network of parks along natural drainages. This not only provides residents with someplace to escape from the buildings and roadways, it reduces damage from flooding. Prior to the establishment of this system, developers often built homes and other structures in drainage areas. When floods came, many a home was damaged. Today, this system of parks with specially constructed ponds has nearly eliminated flooding and saved the city millions of dollars in engineering and construction costs. Low-tech solutions work and save money.

Curitiba promotes participation and cooperation, too. The city recognizes that solutions require the participation of many sectors, including business, government, community groups, and others. Fortunately, other cities are beginning to learn from Curitiba.
self-contained. Known as new urbanist developments or neotraditional towns, these new communities are being built so that residents live within walking or biking distance of shops, stores, and small office buildings—which are often part of the new development itself. At this writing, nearly 100 are in various stages of development in the United States. They are also called new urbanist communities.

Urban centers can also densify by converting empty parking lots (produced by the decline in automobile use in cities) into office buildings. This makes mass transit more efficient and affordable. Unfortunately, the economics of mass transit is currently skewed by massive subsidies to the automobile and gasoline industry. According to national statistics, the automobile is subsidized to the tune of about $300 billion a year—or about $1,500 per car. This subsidy includes expenses for police protection, traffic control, city-paid parking, and other things—expenses that are paid out of general tax revenues. As you learned in Chapter 14, oil is also heavily subsidized. Because of this, sustainable strategies such as mass transit generally have a hard time competing with the automobile. Some critics say that the playing field is tilted heavily in favor of the automobile. Removing the hidden subsidies from oil and automobiles would clearly make mass transit compete more favorably with the automobile.

Jet travel could shift in the coming decades as well. The Swiss have, for example, levied an extra tax on aircraft that do not meet air pollution standards. In 1997, Denmark introduced a $15 fee on all domestic flights that has encouraged people to travel by train instead. High-speed rail, which is growing in popularity in Europe and Japan, could help reduce air travel and shift passengers to a much more efficient form of transit.

**KEY CONCEPTS**

**The Bicycle** For many urban dwellers, the bicycle is not a viable commuting option. Streets are too hilly, or workers live too far from work for practical commuting. In other places, cold winter climates prevent commuting except during the spring, summer, and early fall.

In some cities, however, the bicycle could play a significant role in transporting people. Where climates are mild, streets are not too crowded, and people live relatively close to work, the bicycle can transport surprisingly large numbers of people. Investments that promote bicycle commuting represent one of the cheapest options available to cities and towns.

For decades, the bicycle has been a major means of transportation in many European and Asian countries. In Beijing and other major Chinese cities, bicycles once outnumbered cars many times over, although bikes are being squeezed out by automobiles as China’s economy improves. In some Asian cities, half of all trips are made by bike. Europe is also relatively bicycle friendly. In some cities, bicycles account for 20 to 30% of all trips. In the United States, in contrast, bicycles account for less than 1% of all trips. In Portland, Oregon; Austin, Texas; and other cities, however, bikes are becoming more popular thanks to a “fleet” of city-owned bikes that are left on the sidewalk for anyone who wants them (FIGURE 17-8). If you need to travel five blocks and don’t want to walk, you hop on a bike and pedal to your next meeting or to lunch. Anyone who wants to use the bike you leave by the side of the road can have it.

Following the example set by Europe and Asia, some cities in the United States have laid out extensive bike paths for commuters. Davis, California, is a leader in promoting bicycle transportation. Today, 30% of all commuter transport within the city is by bicycle. Some streets are closed entirely to automobile transport, and 65 kilometers (40 miles) of bike lanes and paths have been established.

Bicycles won’t replace cars, buses, and trains, but they can augment them—in some places more than others. Unfortunately, bicycle sales are declining in Asia because of an increased interest in motorized transport, mostly motorbikes and cars. In some countries, official policies are discouraging bicycle transport in an effort to make travel by car easier.

**KEY CONCEPTS**

In many cities, bicycles already carry a significant number of commuters. The bicycle could help supplement the mass transit systems of cities in the future.
Car Sharing: On the Road—Cheaper and Greener

Do you own your car—or does it own you? If you’re like most people, you’ll answer “yes” to both questions. You own a car that gets you where you want to go, but you’re a slave to it, spending considerable amounts of money (and time) supporting your driving habit.

According to the American Automobile Association, each month Americans pay an average of $700 to own and operate a car. Payments for a new car can easily run $300 to $500 per month. Insurance adds from $75 to $150 per month to the cost of car ownership, and then there’s gasoline, costing another $100 to $200, and maintenance expenses.

Fortunately, if you want the convenience of a car without the expense of ownership, there’s an option for you—it’s called car sharing.

Popular in Europe for almost 3 decades, car sharing has begun to gain momentum in the United States. Two companies ventured—Zipcar and Flexcar, which merged in 2007 and now operate as Zipcar—offer car share programs in cities across the country, including Boston, New York, Chicago, Denver, Los Angeles, Seattle, Washington, D.C., and Portland, Oregon. Even universities, including the University of North Carolina–Chapel Hill, UCLA, and the University of Washington, are jumping on the wagon, saving students money, and helping curb campus traffic congestion and parking problems.

Most car share programs require an application and membership fee, which average about $75. Once you join, vehicles are available for 1 hour to several days. (Special arrangements can be made to rent cars for long trips.) Businesses, families, and individuals can all participate. Car share programs screen applicants using age and traffic violation criteria to eliminate risky clientele. Qualified members are covered by comprehensive and liability insurance when behind the wheel.

Urban car share programs place their cars conveniently throughout the city, in reserved parking lots or spaces. Members pay a small hourly fee to use the car, typically under $10, and a per-mile charge. Some programs give members a certain number of free miles before charging for mileage.

Car share companies use online and phone reservation systems, which allow you to reserve a car in a few quick keystrokes or with a phone call. A computer tells you where the car is and its license plate number. You show up at the site, hold your membership card next to the windshield, where it is read by a scanner, and the doors unlock. The car’s onboard computer sends a signal to company headquarters, indicating your rental period has begun, and activating a billing record.

When you’re done, you return the car to its parking space, lock it, and leave. Your credit card is billed monthly for usage. The program pays for gas, although members are responsible for filling the tank when the gauge drops below the one-quarter mark—using a company credit card. And what if you have a fender-bender? According to former Flexcar spokesperson John Williams, members pay half of the deductible ($500) if they caused the accident; otherwise, there’s no penalty. (Policies vary among different organizations; be sure to inquire first.)

Car sharing programs make it easy to choose a vehicle to meet your needs by offering a wide range of vehicles, from small, efficient commuter cars such as the hybrid-electric Honda Civic or Toyota Prius to larger vehicles for special uses, such as Ford pickups and SUVs. According to Zipcar, more than half of their members say that they tried the service for

Economic Changes Accompanying a Shift to Mass Transit

The automobile industry is the world’s largest manufacturing endeavor and supports a number of other economically important industries. Manufacturers of rubber, glass, steel, radios, and numerous automobile parts will also feel the impacts of the shrinking automobile market. So will the service sector: gas stations, automobile dealerships, and repair services. The shift to more efficient forms of transportation is likely to lead to significant shifts in the world’s economy.

Today, 20 cents of every dollar spent in the United States is directly or indirectly connected to the automobile industry and its suppliers. Eighteen cents of every tax dollar the federal government collects comes from automobile manufacturers and their suppliers.

Although shifting toward a sustainable transportation system could result in a dramatic shift in our economy, experts point out that some of the steel and glass now destined for autos will be used for buses and trains. Many automobile workers will very likely find jobs in plants that produce buses and commuter trains. Many mechanics could shift as well to service the new fleet of more efficient vehicles. Some workers, however, may be forced to find employment in new areas. Helping them adjust to the changes is an important task.

Studies suggest that the employment potential of mass transit, like other sustainable strategies, exceeds that of the current automobile-based economy. A study in Germany showed that spending $1 billion on highways yields 24,000 to 33,000 (direct and indirect) jobs. The same amount spent on mass transit produces 38,000 to 40,000 jobs.
A sustainable transportation system is possible, but it will require a significant restructuring of the current, unsustainable system. Making that transition will require foresight and considerable political will. Many cities are already making changes needed to effect this transition. Denver, Colorado, for instance, has already installed one successful light rail system and is building a second one to serve western suburbs.

Creating sustainable cities and towns is part of the challenge outlined in this text. It will take many years. The technology and knowledge required to make the changes are not barriers, but the political will and the costs of such endeavors surely stand in the way of such a massive shift. Incrementally, however, cities, businesses, and citizens are beginning to make the changes required to create a more sustainable human presence. Automobile manufacturers are making and selling tens of thousands of more efficient hybrid cars and trucks. The hypercar featured in Chapter 15 is currently under development. Biodiesel is currently sold at 10,000 gas stations in the United States, and numerous cities such as Denver are dramatically expanding their light-rail systems. Growth management strategies are popping up in the most unlikely places. The green living tips (Go Green boxes) in this and other chapters list personal actions that you can take to do your part in creating a more sustainable system of transportation and a better future.

If car sharing hasn’t come to your town, consider setting up a program yourself. Across the country, groups of friends, neighbors, and colleagues have established their own car share programs by using cars already owned by individual members of the group or by purchasing cars together.

To make a community car sharing program run smoothly, members should consider providing convenient locations to park the vehicles, and draft agreements on buying fuel, accessing keys, and servicing and insuring the vehicles. A booking system should also be established. The Eugene, Oregon BioCarShare program uses Online Resource Scheduler free software as their scheduling tool. Members log on at the website with their user name and password to reserve a car. Set up as a cooperative, BioCarShare requires members pay a joiner’s fee, which is refundable, and a small monthly membership fee. Like most programs, they also require that drivers pay in proportion to their use, per hour or per mile. Car clubs such as these usually operate with standard insurance coverage—as long as the group or any of its members makes no profit. In most states, car clubs apply for insurance in the club’s name and can list four or five people on a single policy.

Car sharing is an idea that offers the best of both worlds. It ensures people access to transportation while saving them considerable sums of money, and, it is good for the environment.
CRITICAL THINKING

Analysis

Hydrogen is nearly an ideal fuel. It can be made from an abundant resource, water, and is renewable. It produces little, if any, pollution when burned or used to power a fuel cell. In your research, however, you may have discovered that it takes a lot of energy to make hydrogen from water or to strip hydrogen atoms off other molecules such as methane (in natural gas). In fact, it takes a lot of electrical energy. Where does that energy come from? Burning coal or nuclear fuels. The combustion of coal and the use of nuclear fuels both create serious environmental and health problems.

Would it be better to use the electricity directly to power a car or truck, rather than use it to split water to make hydrogen to power a fuel cell to make electricity to run a car or truck? Actually, yes. You may have found studies showing that using electricity directly—using it to power an electric vehicle—is three to four times more efficient than using electricity to create hydrogen to create electricity in a fuel cell to drive an electric motor in a car.

Bear in mind, too, that there are no sources of free hydrogen we can tap into. So, we’ll always need to make it from other molecules, a process that takes a lot of energy.
CRITICAL THINKING AND CONCEPT REVIEW

1. List all the human systems you have relied on since you woke up this morning.
3. Using your critical thinking skills and the knowledge you have gained in your coursework and reading, critically analyze the following statement: “We must restructure human systems to make them compatible with natural systems.”
4. What is meant by the statement “Just because a system is functioning well doesn’t mean that it is sustainable”? Give some examples.
5. List and describe several reasons why most if not all human systems are currently unsustainable.
6. When most people think about creating a sustainable future, they think about designing anew—that is, creating new superefficient homes and autos. Is this sufficient?
7. Critically analyze the following comment: “Our transportation system is just fine. My commute hasn’t changed very much. Air pollution levels are down because of greater efficiency in automobiles and pollution control devices. What’s everyone so concerned about?”
8. What are the traditional functions of land-use planning? How is sustainable land-use planning different?
9. Compare and contrast compact development and dispersed development patterns according to the following criteria: use of land, cost of infrastructure (roads, bridges, and so on), feasibility of mass transit, and air pollution.
10. Describe corridor and satellite development. What are the advantages and disadvantages of each?
11. Imagine that you are a developer. You are about to draw plans to develop a 80-hectare (200-acre) piece of property. Make a list of ways to make the development as environmentally sustainable as possible. Try doing this exercise by addressing one system at a time—for example, energy, waste, water, and transportation.
12. How can differential tax rates, the purchase of development rights, and making growth pay its own way (ending the subsidy for growth) be used to promote more sustainable land use?
13. Using your critical thinking skills, analyze the following assertion: “Land reform in the developing nations will help create a sustainable future.”
14. The text outlined a simplified version of a plan to shift the developed nations such as the United States to a more sustainable system of transportation. Describe this plan and point out its strengths and weaknesses. How could the weaknesses be eliminated?
15. Debate the following statement: “A shift to a transportation system based in large part on mass transit will devastate the global economy and put thousands of people out of work.”

KEY TERMS
cohousing compact development corridor development development right differential tax rate dispersed development greenbelts land-use planning making growth pay its own way mass transit satellite development urban sprawl zoning regulations

REFERENCES AND FURTHER READING
To save on paper and allow for updates, additional reading recommendations and the list of sources for the information discussed in this chapter are available at http://environment.jbpub.com/9e/.

Connect to this book’s website: http://environment.jbpub.com/9e/
The site features eLearning, an online review area that provides quizzes, chapter outlines, and other tools to help you study for your class. You can also follow useful links for in-depth information, research the differing views in the Point/Counterpoints, or keep up on the latest environmental news.

CHAPTER 17: Creating Sustainable Cities, Suburbs, and Towns