CHAPTER 14

# Energy: Some Basics

Manhattan Island from New Jersey during the blackout of August 14, 2003. During rush hour, millions of people walked dark streets to go home.

## LEARNING OBJECTIVES

Understanding the basics of what energy is, as well as the sources and uses of energy, is essential for effective energy planning. After reading this chapter, you should understand . . .

- That energy is neither created nor destroyed but is transformed from one kind to another;
- Why, in all transformations, energy tends to go from a more usable to a less usable form;
- What energy efficiency is and why it is always less than 100%;
- That people in industrialized countries consume a disproportionately large share of the world's total energy, and how efficient use and conservation of energy can help us make better use of global energy resources;
- Why some energy planners propose a business-as-usual approach to energy (based on large power plants using fossil fuels, especially coal), and others a new approach (based on more disseminated and renewable energy sources), and why both of these approaches have positive and negative points;
- Why moving toward global sustainable energy planning with integrated energy planning is an important goal;
- What elements are needed to develop integrated energy planning.

### CASE STUDY

## National Energy Policy: From Coast-to-Coast Energy Crisis to Promoting Energy Independence

The most serious blackout in U.S. history occurred on August 14, 2003. New York City, along with eight states and parts of Canada, suddenly lost electric power at about 4:00 p.m. More than 50 million people were affected, some trapped in elevators or electric trains underground. People streamed into the streets of New York, unsure whether or not the power failure was due to a terrorist attack. Power was restored within 24 hours to most places, but the event was an energy shock that demonstrated our dependence on aging power distribution systems and centralized electric power generation. Terrorists had nothing to do with the blackout, but the event caused harm, anxiety, and financial loss to millions of people.

Seven presidents of the United States since the mid-1970s have attempted to address energy problems and how to become independent of foreign energy sources. The Energy Policy Act of 2005, passed by Congress and signed into law by President George W. Bush in the summer of 2005, has been followed by heated debate about energy policy in the 21st century. A number of topics related to energy are being discussed, including the American Clean Energy and Security Act of 2009, which took a serious step toward energy self-sufficiency in the United States.

The 2009 Act has four parts: (1) *clean energy,* which involves renewable energy, sequestration of carbon, development of clean fuels and vehicles, and a better electricity transmission grid; (2) *energy efficiency,* for buildings, homes, transportation, and utilities; (3) *reduction of carbon dioxide and other greenhouse gases associated with global warming,* including programs to reduce global warming by reducing emissions of carbon dioxide in coming years; and (4) *making the transition to a clean energy economy,* including economic incentives for development of green-energy jobs, exporting clean technology, increasing domestic competitiveness, and finding ways to adapt to global warming.

Today we are more dependent than ever on imported oil. We import about 65% of our oil, often from countries that do not particularly like us. This presents a security risk. Since the 1970s, U.S. consumption of gasoline (for which most oil is used) has risen 50%, while domestic production of oil has dropped by nearly one-half, due in part to a dramatic 50% reduction in Alaska's oil production since the late 1980s. One result was that gasoline prices rose to a peak of $4 per gallon in 2008.

Natural gas has followed a similar pattern with respect to production and consumption since the late 1980s. New power plants today use natural gas as the desired fuel because it is cleaner-burning, resulting in fewer pollutants, and the United States has abundant potential supplies. The problem with natural gas will be to bring production in line with consumption in the future.

Energy planning at the national level in the first five years of the 21st century was marked by an ongoing debate about future supplies of fossil fuels, including coal, oil, and natural gas. Planning objectives have centered on providing a larger supply of coal, natural gas, and, to a lesser extent, oil. Planners concluded that if the United States is to meet electricity demands by the year 2020, over 1,000 new power plants will have to be constructed. When we work out the numbers, this means building about 60 per year between now and 2020—more than one new facility per week!

The key to energy planning is a diversity of energy sources with a better mix of fossil fuels and alternative sources that must eventually replace them. What is apparent is that in the first decades of the 21st century we are going to be continually plagued by dramatic price changes in energy and accompanying shortages. This pattern will continue until we become much more independent from foreign energy sources. Using our remaining fossil fuels, particularly the cleaner fuels such as natural gas, will represent a transitional phase to more sustainable sources. What is really necessary is a major program to develop sources such as wind and solar much more vigorously than has been done in the past or, apparently, will be done in the next few years. If we are unable to make the transition as world production of petroleum peaks and declines, then we will face an energy crisis unsurpassed in our history.

The United States faces serious energy problems. Energy policy, from local to global, has emerged as a central economic concern, national security issue, and environmental question.[1] How we respond to energy issues will largely define who and what we are and will become in the 21st century. With this in mind, in this chapter we explore some of the basic principles associated with what energy is, how much energy we consume, and how we might manage energy for the future.

# 14.1 Outlook for Energy

Energy crises are nothing new. People have faced energy problems for thousands of years, as far back as the early Greek and Roman cultures.

## Energy Crises in Ancient Greece and Rome

The climate in Greece's coastal areas 2,500 years ago was characterized by warm summers and cool winters, much as it is today. To warm their homes in winter, the Greeks used small, charcoal-burning heaters that were not very efficient. Since charcoal is produced from burning wood, wood was their primary source of energy, as it is today for half the world's people.

By the 5th century B.C., fuel shortages had become common, and much of the forested land in many parts of Greece was depleted of firewood. As local supplies diminished, it became necessary to import wood from farther away. Olive groves became sources of fuel; olive wood was turned into charcoal for burning, reducing a valuable resource. By the 4th century B.C., the city of Athens had banned the use of olive wood for fuel.

At about this time, the Greeks began to build their houses facing south, designing them so that the low winter sun entered the houses, providing heat, and the higher summer sun was partially blocked, cooling the houses. Recent excavations of ancient Greek cities suggest that large areas were planned so that individual homes could make maximum use of solar energy, which was a logical answer to their energy problem.[2]

**FIGURE 14.1 Roman bathhouse (lower level) in the town of Bath, England.** The orientation of the bathhouse and the placement of windows are designed to maximize the benefits of passive solar energy.

The use of wood in ancient Rome is somewhat analogous to the use of oil and gas in the United States today. The homes of wealthy Romans about 2,000 years ago had central heating that burned as much as 125 kg (275 lb) of wood every hour. Not surprisingly, local wood supplies were exhausted quickly, and the Romans had to import wood from outlying areas, eventually from as far away as 1,600 km (about 1,000 mi).[2]

The Romans turned to solar energy for the same reasons as the Greeks but with much broader application and success. They used glass windows to increase the effectiveness of solar heat, developed greenhouses to raise food during the winter, and oriented large public bathhouses (some accommodated up to 2,000 people) to use passive solar energy (Figure 14.1). The Romans believed that sunlight in bathhouses was healthy, and it also saved greatly on fuel costs. The use of solar energy in ancient Rome was widespread and resulted in laws to protect a person's right to solar energy. In some areas, it was illegal for one person to construct a building that shaded another's.[2]

The ancient Greeks and Romans experienced an energy crisis in their urban environments. In turning to solar energy, they moved toward what today we call *sustainability*. We are on that same path today as fossil fuels become scarce.

## Energy Today and Tomorrow

The energy situation facing the United States and the world today is in some ways similar to that faced by the early Greeks and Romans. The use of wood in the United States peaked in the 1880s, when the use of coal became widespread. The use of coal, in turn, began to decline after 1920, when oil and gas started to become available. Today, we are facing the global peak of oil production, which is expected by about 2020. Fossil fuel resources, which took millions of years to form, may be essentially exhausted in just a few hundred years.

The decisions we make today will affect energy use for generations. Should we choose complex, centralized energy-production methods, or simpler and widely dispersed methods, or a combination of the two? Which energy sources should be emphasized? Which uses of energy should be emphasized for increased efficiency? How can we develop a sustainable energy policy? There are no easy answers.

The use of fossil fuels, especially oil, improved sanitation, medicine, and agriculture, helping to make possible the global human population increase that we have discussed in other chapters. Many of us are living longer, with a higher standard of living, than people before us. However, burning fossil fuels imposes growing environmental costs, ranging from urban pollution to a change in the global climate.

One thing certain about the energy picture for tomorrow is that it will involve living with uncertainty when it comes to energy availability and cost. The sources of energy and the patterns of energy use will undoubtedly change. We can expect problems, with growing demand and insufficient supply leading to higher costs. Supplies will continue to be regulated and could be disrupted. Oil embargoes could cause significant economic impact in the United States and other countries, and a war or revolution in a petroleum-producing country would significantly reduce petroleum exports.

It is clear that we need to rethink our entire energy policy in terms of sources, supply, consumption, and environmental concerns. We can begin by understanding basic facts about what energy is.

## 14.2 Energy Basics

The concept of energy is somewhat abstract: You cannot see it or feel it, even though you have to pay for it.[3] To understand energy, it is easiest to begin with the idea of a force. We all have had the experience of exerting force by pushing or pulling. The strength of a force can be measured by how much it accelerates an object.

What if your car stalls going up a hill and you get out to push it uphill to the side of the road (Figure 14.2)? You apply a force against gravity, which would otherwise cause the car to roll downhill. If the brake is on, the brakes, tires, and bearings may heat up from friction. The longer the distance over which you exert force in pushing the car, the greater the change in the car's position and the greater the amount of heat from friction in the brakes, tires, and bearings. In physicists' terms, exerting the force over the distance moved is work. That is, **work** is the product of a force times a distance. Conversely, energy is the ability to do work. Thus, if you push hard but the car doesn't move, you have exerted a force but have not done any work (according to the definition), even if you feel very tired and sweaty.[3]

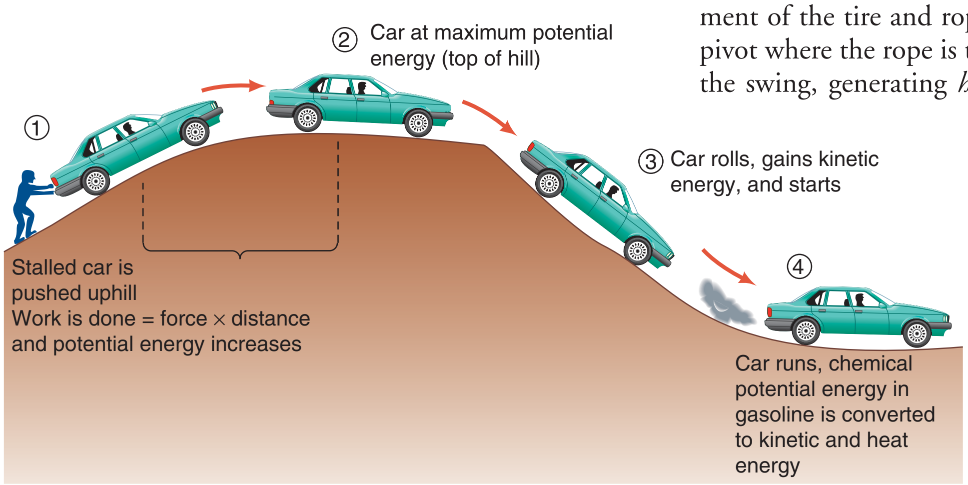

FIGURE 14.2 **Some basic energy concepts**, including potential energy, kinetic energy, and heat energy.

In pushing your stalled car, you have moved it against gravity and caused some of its parts (brakes, tires, bearings) to be heated. These effects have something in common: They are forms of energy. You have converted chemical energy in your body to the energy of motion of the car (kinetic energy). When the car is higher on the hill, the potential energy of the car has been increased, and friction produces heat energy.

Energy is often converted or transformed from one kind to another, but the total energy is always conserved. The principle that energy cannot be created or destroyed but is always conserved is known as the **first law of thermodynamics.** Thermodynamics is the science that keeps track of energy as it undergoes various transformations from one type to another. We use the first law to keep track of the quantity of energy.[4]

To illustrate the conservation and conversion of energy, think about a tire swing over a creek (Figure 14.3). When the tire swing is held in its highest position, it is not moving. It does contain stored energy, however, owing to its position. We refer to the stored energy as *potential energy*. Other examples of potential energy are the gravitational energy in water behind a dam; the chemical energy in coal, fuel oil, and gasoline, as well as in the fat in your body; and nuclear energy, which is related to the forces binding the nuclei of atoms.[3]

The tire swing, when released from its highest position, moves downward. At the bottom (straight down), the speed of the tire swing is greatest, and no potential energy remains. At this point, all the swing's energy is the energy of motion, called *kinetic energy*. As the tire swings back and forth, the energy continuously changes between the two forms, potential and kinetic. However, with each swing, the tire slows down a little more and goes a little less high because of friction created by the movement of the tire and rope through air and friction at the pivot where the rope is tied to the tree. The friction slows the swing, generating *heat energy*, which is energy from random motion of atoms and molecules. Eventually, all the energy is converted to heat and emitted to the environment, and the swing stops.[3]

The example of the swing illustrates the tendency of energy to dissipate and end up as heat. Indeed, physicists have found that it is possible to change all the gravitational energy in a tire swing (a type of pendulum) to heat. However, it is impossible to change all the

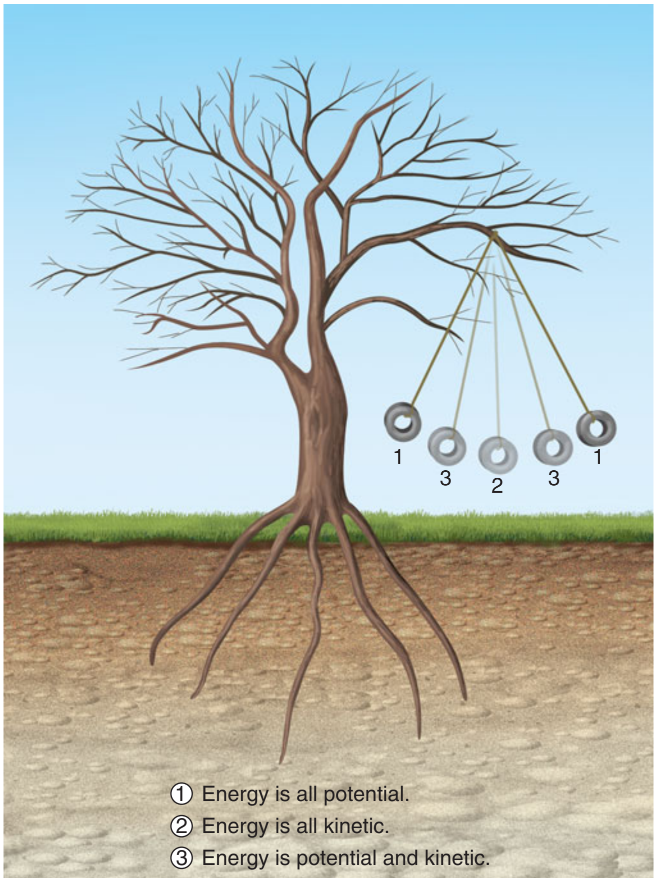

**FIGURE 14.3** **Diagram of a tire swing**, illustrating the relation between potential and kinetic energy.

heat energy thus generated back into potential energy. Energy is conserved in the tire swing. When the tire swing finally stops, all the initial gravitational potential energy has been transformed by way of friction to heat energy. If the same amount of energy, in the form of heat, were returned to the tire swing, would you expect the swing to start again? The answer is no! What, then, is used up? It is not energy because energy is always conserved. What is used up is the energy *quality*—the availability of the energy to perform work. The higher the quality of the energy, the more easily it can be converted to work; the lower the energy quality, the more difficult to convert it to work.

This example illustrates another fundamental property of energy: Energy always tends to go from a more usable (higher-quality) form to a less usable (lower-quality) form. This is the **second law of thermodynamics**, and it means that when you use energy, you lower its quality.

Let's return to the example of the stalled car, which you have now pushed to the side of the road. Having pushed the car a little way uphill, you have increased its potential energy. You can convert this to kinetic energy by letting it roll back downhill. You engage the gears to restart the car. As the car idles, the potential chemical energy (from the gasoline) is converted to waste heat energy and other energy forms, including electricity to charge the battery and play the radio.

Why can't we collect the wasted heat and use it to run the engine? Again, as the second law of thermodynamics tells us, once energy is degraded to low-quality heat, it can never regain its original availability or energy grade. When we refer to low-grade heat energy, we mean that relatively little of it is available to do useful work. High-grade energy, such as that of gasoline, coal, or natural gas, has high potential to do useful work. The biosphere continuously receives high-grade energy from the sun and radiates low-grade heat to the depths of space.[3, 4]

## 14.3 Energy Efficiency

Two fundamental types of energy efficiencies are derived from the first and second laws of thermodynamics: first-law efficiency and second-law efficiency. **First-law efficiency** deals with the amount of energy without any consideration of the quality or availability of the energy. It is calculated as the ratio of the actual amount of energy delivered where it is needed to the amount of energy supplied to meet that need. Expressions for efficiencies are given as fractions; multiplying the fraction by 100 converts it to a percentage. As an example, consider a furnace system that keeps a home at a desired temperature of 18°C (65°F) when the outside temperature is 0°C (32°F). The furnace, which burns natural gas, delivers 1 unit of heat energy to the house for every 1.5 units of energy extracted from burning the fuel. That means it has a first-law efficiency of 1 divided by 1.5, or 67% (see Table 14.1 for other examples).[4] The "unit" of energy for our furnace is arbitrary for the purpose of discussion; we also could use the British thermal unit (Btu) or some other units (see A Closer Look 14.1).

First-law efficiencies are misleading because a high value suggests (often incorrectly) that little can be done to save energy through additional improvements in efficiency. This problem is addressed by the use of second-law efficiency. **Second-law efficiency** refers to how well matched the energy end use is with the quality of the energy source. For our home-heating example, the second-law efficiency would compare the minimum energy necessary to heat the home to the energy actually used by the gas furnace. If we calculated the second-law efficiency (which is beyond the scope of this discussion), the result might be 5%—much lower than the first-law efficiency of 67%.[4] (We will see why later.) Table 14.1 also lists some second-law efficiencies for common uses of energy.

Values of second-law efficiency are important because low values indicate where improvements in energy technology and planning may save significant amounts of high-quality energy. Second-law efficiency tells us whether the energy quality is appropriate to the task. For example, you could use a welder's acetylene blowtorch to light a candle, but a match is much more efficient (and safer as well).

**Table 14.1** EXAMPLES OF FIRST- AND SECOND-LAW EFFICIENCIES

| ENERGY (END USE) | FIRST-LAW EFFICIENCY (%) | WASTE HEAT (%) | SECOND-LAW EFFICIENCY (%) | POTENTIAL FOR SAVINGS |
|---|---|---|---|---|
| Incandescent lightbulb | 5 | 95 | | |
| Fluorescent light | 20 | 80 | | |
| Automobile | 20-25 | 75-80 | 10 | Moderate |
| Power plants (electric); fossil fuel and nuclear | 30-40 | 60-70 | 30 | Low to moderate |
| Burning fossil fuels (used directly for heat) | 65 | 35 | | |
| Water heating | | | 2 | Very high |
| Space heating and cooling | | | 6 | Very high |
| All energy (U.S.) | 50 | 50 | 10-15 | High |

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# A CLOSER LOOK 14.1

## Energy Units

When we buy electricity by the kilowatt-hour, what are we buying? We say we are buying energy, but what does that mean? Before we go deeper into the concepts of energy and its uses, we need to define some basic units.

The fundamental energy unit in the metric system is the *joule;* 1 joule is defined as a force of 1 newton* applied over a distance of 1 meter. To work with large quantities, such as the amount of energy used in the United States in a given year, we use the unit *exajoule*, which is equivalent to $10^{18}$ (a billion billion) joules, roughly equivalent to 1 quadrillion, or $10^{15}$, Btu, referred to as a *quad*. To put these big numbers in perspective, the United States today consumes approximately 100 exajoules (or quads) of energy per year, and world consumption is about 425 exajoules (quads) annually.

In many instances, we are particularly interested in the rate of energy use, or *power*, which is energy divided by time. In the metric system, power may be expressed as joules per second, or *watts* (W); 1 joule per second is equal to 1 watt. When larger power units are required, we can use multipliers, such as *kilo*-(thousand), *mega*- (million), and *giga*-(billion). For example, a modern nuclear power plant's electricity production rate is 1,000 megawatts (MW) or 1 gigawatt (GW).

Sometimes it is useful to use a hybrid energy unit, such as the watt-hour (Wh); remember, energy is power multiplied by time. Electrical energy is usually expressed and sold in *kilowatt-hours* (kWh, or 1,000 Wh). This unit of energy is 1,000 W applied for 1 hour (3,600 seconds), the equivalent energy of 3,600,000 J (3.6 MJ).

The average estimated electrical energy in kilowatt-hours used by various household appliances over a period of a year is shown in Table 14.2. The total energy used annually is the power rating of the appliance multiplied by the time the appliance was actually used. The appliances that use most of the electrical energy are water heaters, refrigerators, clothes driers, and washing machines. A list of common household appliances and the amounts of energy they consume is useful in identifying the ones that might help save energy through conservation or improved efficiency.

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* A newton (N) is the force necessary to produce an acceleration of 1 m per sec ($m/s^2$) to a mass of 1 kg.

**Table 14.2** POWER USE OF TYPICAL HOUSEHOLD APPLIANCES IN WATTS (W)

| APPLIANCE | POWER (W) |
|---|---|
| Clock | 2 |
| Coffee maker | 900–1200 |
| Clothes washer | 350–500 |
| Clothes dryer | 1800–5000 |
| Dishwasher | 1200–2400 (using the drying feature greatly increases energy consumption) |
| Electric blanket - *Single/Double* | 60/100 |
| Fans | |
| Ceiling | 65–175 |
| Window | 55–250 |
| Furnace | 750 |
| Whole house | 240–750 |
| Hair dryer | 1200–1875 |
| Heater (*portable*) | 750–1500 |
| Clothes iron | 1000–1800 |
| Microwave oven | 750–1100 |
| Personal computer | |
| CPU - awake/asleep | 120/30 or less |
| Monitor - awake/asleep | 150/30 or less |
| Laptop | 50 |
| Radio (*stereo*) | 70–400 |
| Refrigerator (*frost-free, 16 cubic feet*) | 725 |
| Televisions (color) | |
| 19” | 65–110 |
| 36” = 133 W | |
| 53”–61” Projection | 170 |
| Flat screen | 120 |
| Toaster | 800–1400 |
| Toaster oven | 1225 |
| VCR/DVD | 17–21/20–25 |
| Vacuum cleaner | 1000–1440 |
| Water heater (*40 gallon*) | 4500–5500 |
| Water pump (*deep well*) | 250–1100 |
| Water bed (*with heater, no cover*) | 120–380 |

*You can use this formula below to estimate an appliance’s energy use:

Wattage × Hours Used Per Day ÷ 1000 = Daily Kilowatt-hour (kWh) consumption: remember 1kW = 1,000 watts, which is why we divide by 1,000

Multiply by the number of days you use a particular appliance during the year for the annual energy consumption.

You can calculate the annual cost to run an appliance by multiplying the kWh per year by your local utility’s rate per kWh consumed.

Example: Personal Computer and Monitor: (120 + 150 Watts × 4 hours/day × 365 days/year) ÷ 1000 ≅ 394 kWh × 11 cents/kWh (approx national average) ≅ $43.34/year

*Note: To estimate the number of hours that a refrigerator actually operates at its maximum wattage, divide the total time the refrigerator is plugged in by three. Refrigerators, although turned “on” all the time, cycle on and off as needed to maintain interior temperatures.

*Source*: Modified from U.S. Department of Energy. Your Home. accessed January 27, 2010 at http://www.energysavers.gov

We are now in a position to understand why the second-law efficiency is so low (5%) for the house-heating example discussed earlier. This low efficiency implies that the furnace is consuming too much high-quality energy in carrying out the task of heating the house. In other words, the task of heating the house requires heat at a relatively low temperature, near 18°C (65°F), not heat with temperatures in excess of 1,000°C (1,832°F), such as is generated inside the gas furnace. Lower-quality energy, such as solar energy, could do the task and yield a higher second-law efficiency because there is a better match between the required energy quality and the house-heating end use. Through better energy planning, such as matching the quality of energy supplies to the end use, higher second-law efficiencies can be achieved, resulting in substantial savings of high-quality energy.

Examination of Table 14.1 indicates that electricity-generating plants have nearly the same first-law and second-law efficiencies. These generating plants are examples of heat engines. A heat engine produces work from heat. Most of the electricity generated in the world today comes from *heat engines* that use nuclear fuel, coal, gas, or other fuels. Our own bodies are examples of heat engines, operating with a capacity (power) of about 100 watts and fueled indirectly by solar energy. (See A Closer Look 14.1 for an explanation of watts and other units of energy.) The internal combustion engine (used in automobiles) and the steam engine are additional examples of heat engines. A great deal of the world's energy is used in heat engines, with profound environmental effects, such as thermal pollution, urban smog, acid rain, and global warming.

The maximum possible efficiency of a heat engine, known as *thermal efficiency*, was discovered by the French engineer Sadi Carnot in 1824, before the first law of thermodynamics was formulated.[5] Modern heat engines have thermal efficiencies that range between 60 and 80% of their ideal Carnot efficiencies. Modern 1,000-megawatt (MW) electrical generating plants have thermal efficiencies ranging between 30 and 40%; that means at least 60–70% of the energy input to the plant is rejected as waste heat. For example, assume that the electric power output from a large generating plant is 1 unit of power (typically 1,000 MW). Producing that 1 unit of power requires 3 units of input (such as burning coal) at the power plant, and the entire process produces 2 units of waste heat, for a thermal efficiency of 33%. The significant number here is the waste heat, 2 units, which amounts to twice the actual electric power produced.

Electricity may be produced by large power plants that burn coal or natural gas, by plants that use nuclear fuel, or by smaller producers, such as geothermal, solar, or wind sources (see Chapters 15, 16, and 17). Once produced, the electricity is fed into the grid, which is the network of power lines, or the distribution system. Eventually it reaches homes, shops, farms, and factories, where it provides light and heat and also drives motors and other machinery used by society. As electricity moves through the grid, losses take place. The wires that transport electricity (power lines) have a natural resistance to electrical flow. Known as *electrical resistivity*, this resistance converts some of the electric energy in the transmission lines to heat energy, which is radiated into the environment surrounding the lines.

## 14.4 Energy Sources and Consumption

People living in industrialized countries make up a relatively small percentage of the world's population but consume a disproportionate share of the total energy consumed in the world. For example, the United States, with only 5% of the world's population, uses approximately 20% of the total energy consumed in the world. There is a direct relationship between a country's standard of living (as measured by gross national product) and energy consumption per capita.

After the peak in oil production, expected in 2020–2050, oil and gasoline will be in shorter supply and more expensive. Before then, use of these fuels may be curtailed in an effort to lessen global climate change. As a result, within the next 30 years both developed and developing countries will need to find innovative ways to obtain energy. In the future, affluence may be related as closely to more efficient use of a wider variety of energy sources as it is now to total energy consumption.

### Fossil Fuels and Alternative Energy Sources

Today, approximately 90% of the energy consumed in the United States is derived from petroleum, natural gas, and coal. Because they originated from plant and animal material that existed millions of years ago, they are called fossil fuels. They are forms of stored solar energy that are part of our geologic resource base, and they are essentially nonrenewable. Other sources of energy—geothermal, nuclear, hydropower, and solar, among others—are referred to as *alternative* energy sources because they may serve as alternatives to fossil fuels in the future. Some of them, such as solar and wind, are not depleted by consumption and are known as *renewable energy* sources.

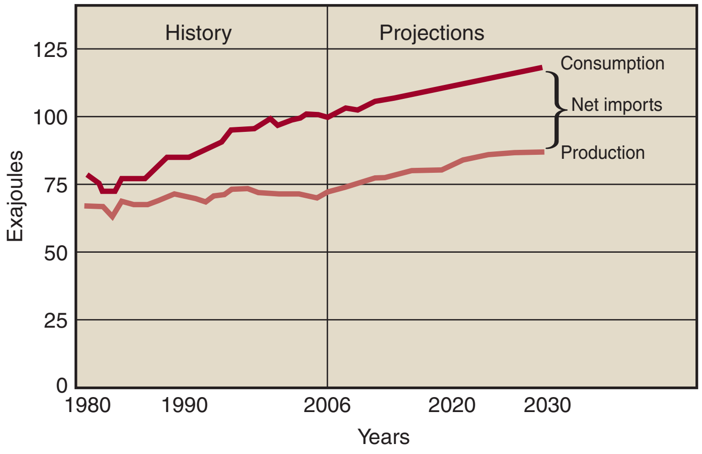
The shift to alternative energy sources may be gradual as fossil fuels continue to be used, or it could be accelerated by concern about potential environmental effects of burning fossil fuels. Regardless of which path we take, one thing is certain: Fossil fuels are finite. It took millions of years to form them, but they will be depleted in only a few hundred years of human history. Using even the most optimistic predictions, the fossil fuel epoch that started with the Industrial Revolution will represent only about 500 years of human history. Therefore, although fossil fuels have been extremely significant in the development of modern civilization, their use will be a brief event in the span of human history.[6, 7]

### *Energy Consumption in the United States*

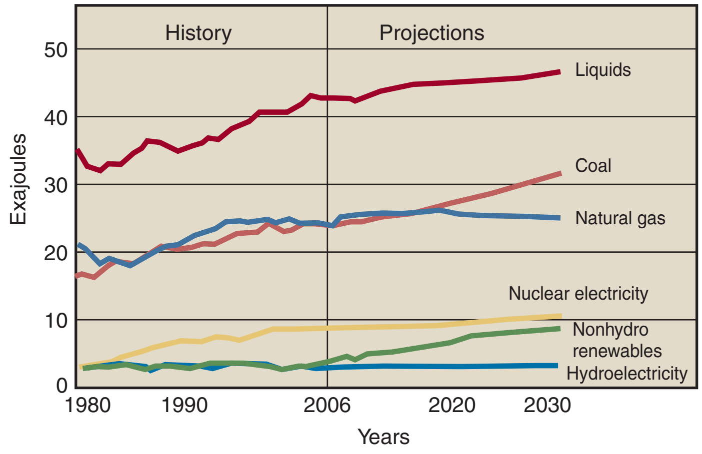
Energy consumption in the United States from 1980 and projected to 2030 is shown in Figure 14.4. The figure dramatically illustrates our ongoing dependence on the three major fossil fuels: coal, natural gas, and petroleum. From approximately 1950 through the late 1970s, energy consumption soared, from about 30 exajoules to 75 exajoules. (Energy units are defined in A Closer Look 14.1.) Since about 1980, energy consumption has risen by only about 25 exajoules. This is encouraging because it suggests that policies promoting energy-efficiency improvements (such as requiring new automobiles to be more fuel-efficient and buildings to be better insulated) have been at least partially successful.

What is not shown in the figure, however, is the huge energy loss. For example, energy consumption in the United States in 1965 was approximately 50 exajoules, of which only about half was used effectively. Energy losses were about 50% (the number shown earlier in Table 14.1 for all energy). In 2009, energy consumption in the United States was about 100 exajoules, and again about 50% was lost in conversion processes. Energy losses in 2009 were about equal to total U.S. energy consumption in 1965! The largest energy losses are associated with the production of electricity and with transportation, mostly through the use of heat engines, which produce waste heat that is lost to the environment.

Another way to examine energy use is to look at the generalized energy flow of the United States by end use for a particular year (Figure 14.5). In 2008 we imported considerably more oil than we produced (we import about 65% of the oil we use), and our energy consumption was fairly evenly distributed in three sectors: residential/commercial, industrial, and transportation. It is clear that we remain dangerously vulnerable to changing world conditions affecting the production and delivery of crude oil. We need to evaluate the entire spectrum of potential energy sources to ensure that sufficient energy will be available in the future, while sustaining environmental quality.



(a) Total energy production and consumption, 1980-2030 (quadrillion Btu)



(b) Energy consumption by fuel, 1980-2030 (quadrillion Btu)

FIGURE 14.4 **U.S. energy from 1980 and projected to 2030.** **(a)** Total consumption and production; **(b)** consumption by source. (*Source:* Department of Energy, Energy Information Agency, *Annual Report 2008*.) These forecasts are conservative in terms of expected increases in alternative energy.

## 14.5 Energy Conservation, Increased Efficiency, and Cogeneration

There is a movement to change patterns of energy consumption in the United States through such measures as conservation, improved energy efficiency, and cogeneration. **Conservation** of energy refers simply to using less energy and adjusting our energy needs and uses to minimize the amount of high-quality energy necessary for a given task.[8] Increased **energy efficiency** involves designing equipment to yield more energy output from a given amount of energy input (first-law efficiency) or better matches between energy source and end use (second-law efficiency). **Cogeneration** includes a number of processes designed to capture and use waste heat, rather than simply releasing it into the atmosphere, water, or other parts of the environment as a thermal pollutant. In other words, we design energy systems and power plants to provide energy more than once[9]—that is, to use it a second time, at a lower temperature, but possibly to use it in more than one way as well.

An example of cogeneration is the *natural gas combined cycle power plant* that produces electricity in two ways: gas cycle and steam cycle. In the gas cycle, the natural gas fuel is burned in a gas turbine to produce electricity. In the steam cycle, hot exhaust from the gas turbine is used to create steam that is fed into a steam generator to produce additional electricity. The combined cycles capture waste heat from the gas cycle, nearly doubling the efficiency of the power plant from about 30 to 50–60%. Energy conservation is particularly attractive because it provides more than a one-to-one savings. Remember that it takes 3 units of fuel such as coal to produce 1 unit of power such as electricity (two-thirds is waste heat). Therefore, not using (conserving) 1 unit of power saves 3 units of fuel!

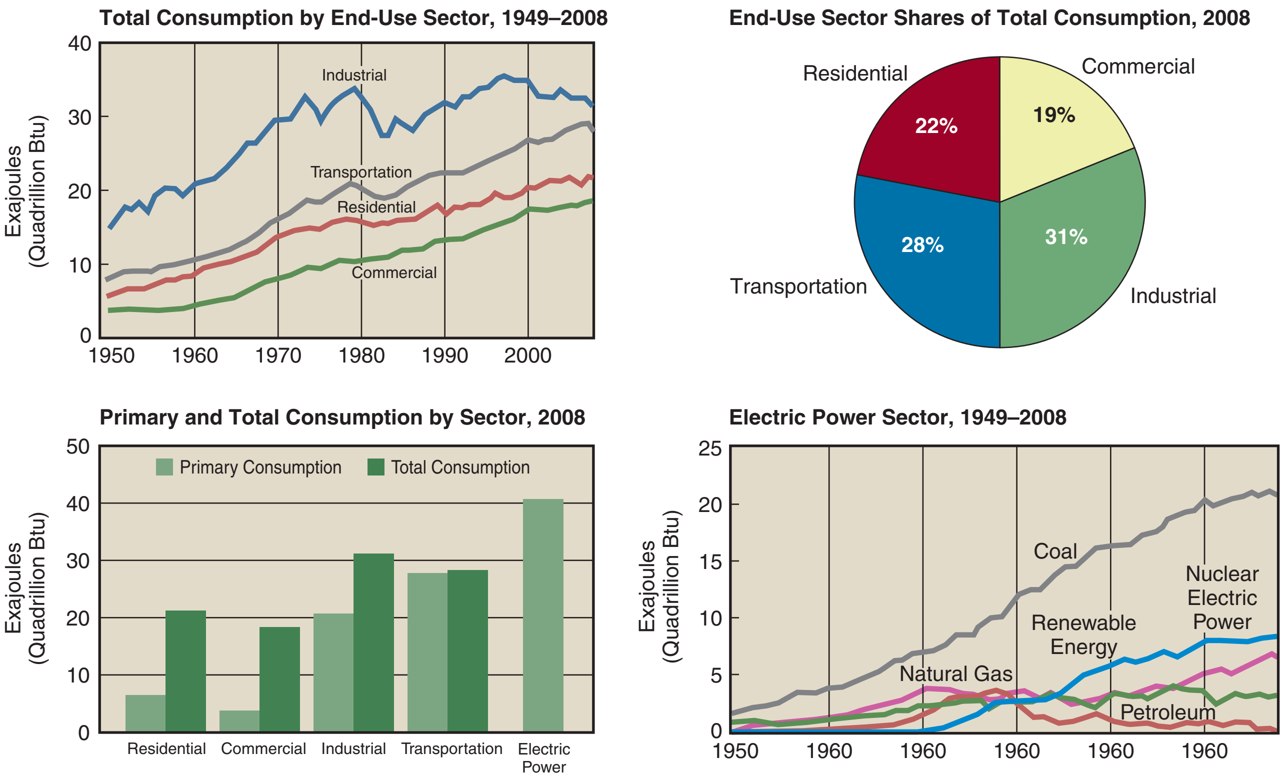


**FIGURE 14.5** **Energy consumption in the United States by sector (approximate).** Total primary consumption is the amount of fossil and renewable fuels consumed. Total consumption refers to fossil and renewable fuels consumed plus electricity used. (*Source:* U.S. Energy Information Administration, *Annual Energy Review, 2008.*)

These three concepts—energy conservation, energy efficiency, and cogeneration—are all interlinked. For example, when big, coal-burning power stations produce electricity, they may release large amounts of heat into the atmosphere. Cogeneration, by using that waste heat, can increase the overall efficiency of a typical power plant from 33% to as much as 75%, effectively reducing losses from 67 to 25%. Cogeneration also involves generating electricity as a by-product of industrial processes that produce steam as part of their regular operations. Optimistic energy forecasters estimate that eventually we may meet approximately one-half the electrical power needs of industry through cogeneration.[8, 9] Another source has estimated that cogeneration could provide more than 10% of the power capacity of the United States.

The average first-law efficiency of only 50% (Table 14.1) illustrates that large amounts of energy are currently lost in producing electricity and in transporting people and goods. Innovations in how we produce energy for a particular use can help prevent this loss, raising second-law efficiencies. Of particular importance will be energy uses with applications below 100°C (212°F), because a large portion of U.S. energy consumption for uses below 300°C, or 572°F, is for space heating and water heating.

In considering where to focus our efforts to improve energy efficiency, we need to look at the total energy-use picture. In the United States, space heating and cooling of homes and offices, water heating, industrial processes (to produce steam), and automobiles account for nearly 60% of the total energy use, whereas transportation by train, bus, and airplane accounts for only about 5%. Therefore, the areas we should target for improvement are building design, industrial energy use, and automobile design. We note, however, that debate continues as to how much efficiency improvements and conservation can reduce future energy demands and the need for increased energy production from traditional sources, such as fossil fuel.

## Building Design

A spectrum of possibilities exists for increasing energy efficiency and conservation in residential buildings. For new homes, the answer is to design and construct homes that require less energy for comfortable living.[8] For example, we can design buildings to take advantage of passive solar potential, as did the early Greeks and Romans and the Native American cliff dwellers. (Passive solar energy systems collect solar heat without using moving parts.) Windows and overhanging structures can be positioned so that the overhangs shade the windows from solar energy in summer, thereby keeping the house cool, while allowing winter sun to penetrate the windows and warm the house.

The potential for energy savings through architectural design for older buildings is extremely limited. The position of the building on the site is already established, and reconstruction and modifications are often not

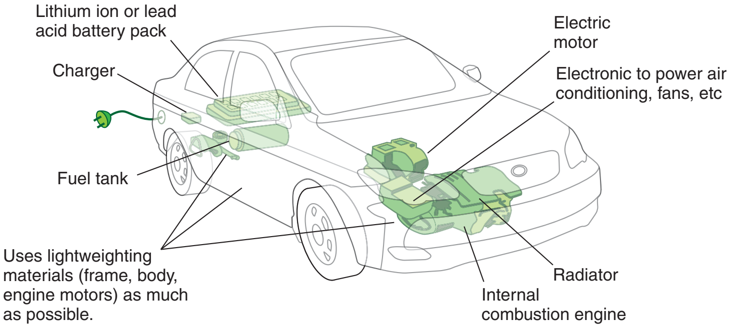


**FIGURE 14.6** Idealized diagram of a plug-in hybrid car.

cost-effective. The best approach to energy conservation for these buildings is insulation, caulking, weather stripping, installation of window coverings and storm windows, and regular maintenance.

Ironically, buildings constructed to conserve energy are more likely to develop indoor air pollution due to reduced ventilation. In fact, air pollution is emerging as one of our most serious environmental problems. Potential difficulties can be reduced by better designs for air-circulation systems that purify indoor air and bring in fresh, clean air. Construction that incorporates environmental principles is more expensive owing to higher fees for architects and engineers, as well as higher initial construction costs. Nevertheless, moving toward improved design of homes and residential buildings to conserve energy remains an important endeavor.

## Industrial Energy

The rate of increase in energy use (consumption) leveled off in the early 1970s. Nevertheless, industrial production of goods (automobiles, appliances, etc.) continued to grow significantly. Today, U.S. industry consumes about one-third of the energy produced. The reason we have had higher productivity with lower growth of energy use is that more industries are using cogeneration and more energy-efficient machinery, such as motors and pumps designed to use less energy.[8, 10]

### *Automobile Design*

The development of fuel-efficient automobiles has steadily improved during the last 30 years. In the early 1970s, the average U.S. automobile burned approximately 1 gallon of gas for every 14 miles traveled. By 1996, the miles per gallon (mpg) had risen to an average of 28 for highway driving and as high as 49 for some automobiles.[11] Fuel consumption rates did not improve much from 1996 to 1999. In 2004, many vehicles sold were SUVs and light trucks with fuel consumption of 10–20 mpg. A loophole in regulations permits these vehicles to have poorer fuel consumption than conventional automobiles.[11] As a result of higher gasoline prices, sales of larger SUVs declined in 2006, but smaller SUVs remain popular as consumers are apparently sacrificing size for economy (up to a point). Today the fuel consumption of some hybrid (gasoline-electric) vehicles exceeds 90 mpg on the highway and 60 mpg in the city. This improvement stems from increased fuel efficiency; smaller cars with engines constructed of lighter materials; and hybrid cars, which combine a fuel-burning engine and an electric motor. Demand for hybrid vehicles is growing rapidly and will be met with the development of more advanced rechargeable batteries (plug-in hybrids; see Figure 14.6).

The real change in cars is coming. What it will be and when are not entirely known, but it may be a transformation to all-electric cars. Miles per gallon will not be the issue, but where and how we produce the electricity will be.

## Values, Choices, and Energy Conservation

A potentially effective method of conserving energy is to change our behavior by using less energy. This involves our values and the choices we make to act at a local level to address global environmental problems, such as human-induced warming caused by burning fossil fuels. For example, we make choices as to how far we commute to school or work and what method of transport we use to get there. Some people commute more than an hour by car to get to work, while others ride a bike, walk, or take a bus or train. Other ways of modifying behavior to conserve energy include the following:

- Using carpools to travel to and from work or school
- Purchasing a hybrid car (gasoline-electric)
- Turning off lights when leaving rooms
- Taking shorter showers (conserves hot water)
- Putting on a sweater and turning down the thermostat in winter
- Using energy-efficient compact fluorescent lightbulbs
- Purchasing energy-efficient appliances
- Sealing drafts in buildings with weather stripping and caulk
- Better insulating your home
- Washing clothes in cold water whenever possible
- Purchasing local foods rather than foods that must be brought to market from afar
- Reducing standby power for electronic devices and appliances by using power strips and turning them off when not in use

What other ways of modifying your behavior would help conserve energy?

# 14.6 Sustainable-Energy Policy

Energy policy today is at a crossroads. One path leads to the "business-as-usual" approach—find greater amounts of fossil fuels, build larger power plants, and go on using energy as freely as we always have. The business-as-usual path is more comfortable—it requires no new thinking; no realignment of political, economic, or social conditions; and little anticipation of coming reductions in oil production.

People heavily invested in the continued use of fossil fuels and nuclear energy often favor the traditional path. They argue that much environmental degradation around the world has been caused by people who have been forced to use local resources, such as wood, for energy, leading to the loss of plant and animal life and increasing soil erosion. They argue that the way to solve these environmental problems is to provide cheap, high-quality energy, such as fossil fuels or nuclear energy.

In countries like the United States, with sizable resources of coal and natural gas, people supporting the business-as-usual path argue that we should exploit those resources while finding ways to reduce their environmental impact. According to these proponents, we should (1) let the energy industry develop the available energy resources and (2) let industry, free from government regulations, provide a steady supply of energy with less total environmental damage.

The previous U.S. energy plan, suggested by then President George W. Bush, was largely a business-as-usual proposal: Find and use more coal, oil, and natural gas; use more nuclear power; and build more than 1,000 new fossil fuel plants in the next 20 years. Energy conservation and development of alternative energy sources, while encouraged, were not considered of primary importance.

A visionary path for energy policy was suggested more than 30 years ago by Amory Lovins.[12] That path focuses on energy alternatives that emphasize energy quality and are renewable, flexible, and environmentally more benign than those of the business-as-usual path. As defined by Lovins, these alternatives have the following characteristics:

- They rely heavily on renewable energy resources, such as sunlight, wind, and biomass (wood and other plant material).
- They are diverse and are tailored for maximum effectiveness under specific circumstances.
- They are flexible, accessible, and understandable to many people.
- They are matched in energy quality, geographic distribution, and scale to end-use needs, increasing second-law efficiency.

Lovins points out that people are not particularly interested in having a certain amount of oil, gas, or electricity delivered to their homes; they are interested in having comfortable homes, adequate lighting, food on the table, and energy for transportation.[12] According to Lovins, only about 5% of end uses require high-grade energy, such as electricity. Nevertheless, a lot of electricity is used to heat homes and water. Lovins shows that there is an imbalance in using nuclear reactions at extremely high temperatures and in burning fossil fuels at high temperatures simply to meet needs where the necessary temperature increase may be only a few 10s of degrees. He considers such large discrepancies wasteful and a misallocation of high-quality energy.

## Energy for Tomorrow

The availability of energy supplies and the future demand for energy are difficult to predict because the technical, economic, political, and social assumptions underlying predictions are constantly changing. In addition, seasonal and regional variations in energy consumption must also be considered. For example, in areas with cold winters and hot, humid summers, energy consumption peaks during the winter months (from heating) and again in the summer (from air-conditioning). Regional variations in energy consumption are significant. For example, in the United States as a whole, the transportation sector uses about one-fourth of the energy consumed. However, in California, where people often commute long distances to work, about one-half of the energy is used for transportation, more than double the national average. Energy sources, too, vary by region. For example, in the eastern and southwestern United States, the fuel of choice for power plants is often coal, but power plants on the West Coast are more likely to burn oil or natural gas or use hydropower from dams to produce electricity.

Future changes in population densities, as well as intensive conservation measures, will probably alter existing patterns of energy use. This might involve a shift to more reliance on alternative (particularly renewable) energy sources.[13, 14] Energy consumption in the United States in the year 2050 may be about 160 exajoules. What will be the energy sources for the anticipated growth in energy consumption? Will we follow our past policy of business as usual (coal, oil, nuclear), or will we turn more to alternative energy sources (wind, solar, geothermal)? What is clear is that the mix of energy sources in 2030 will be different from today's and more diversified.[13-15]

All projections of specific sources and uses of energy in the future must be considered speculative. Perhaps most speculative of all is the idea that we really can meet most of our energy needs with alternative, renewable energy sources in the next several decades. From an energy viewpoint, the next 20 to 30 years, as we move through the maximum production of petroleum, will be crucial to the United States and to the rest of the industrialized world.

The energy decisions we make in the very near future will greatly affect both our standard of living and our quality of life. From an optimistic point of view, we have the necessary information and technology to ensure a bright, warm, lighted, and mobile future. But time may be running out, and we need action now. We can continue to take things as they come and live with the results of our present dependence on fossil fuels, or we can build a sustainable energy future based on careful planning, innovative thinking, and a willingness to move from our dependence on petroleum.

U.S. energy policy for the 21st century is being discussed seriously, and significant change in policy is likely. Some of the recommendations are as follows:

- Promote conventional energy sources: Use more natural gas to reduce our reliance on energy from foreign countries.
- Encourage alternative energy: Support and subsidize wind, solar, geothermal, hydrogen, and biofuels (ethanol and biodiesel).
- Provide for energy infrastructure: Ensure that electricity is transmitted over dependable, modern infrastructure.
- Promote conservation measures: Set higher efficiency standards for buildings and for household products. Require that waste heat from power generation and industrial processes be used to produce electricity or other products. Recommend stronger fuel-efficiency standards for cars, trucks, and SUVs. Provide tax credits for installing energy-efficient windows and appliances in homes and for purchasing fuel-efficient hybrids or clean-diesel vehicles.
- Carefully evaluate the pros and cons of nuclear power, which can generate large amounts of electricity without emitting greenhouse gases, but has serious negatives as well.
- Promote research: Develop new alternative energy sources; find new, innovative ways to improve existing coal plants and to help construct cleaner coal plants; determine whether it is possible to extract vast amounts of oil trapped in oil shale and tar sands without harming the environment; and develop pollution-free, electric automobiles.

Which of the above points will become policy in future years is not known, but parts of the key ideas will move us toward sustainable energy.

**Integrated, Sustainable Energy Management** The concept of **integrated energy management** recognizes that no single energy source can provide all the energy required by the various countries of the world.[16] A range of options that vary from region to region will have to be employed. Furthermore, the mix of technologies and sources of energy will involve both fossil fuels and alternative, renewable sources.

A basic goal of integrated energy management is to move toward **sustainable energy development** that is implemented at the local level. Sustainable energy development would have the following characteristics:

- It would provide reliable sources of energy.
- It would not destroy or seriously harm our global, regional, or local environments.
- It would help ensure that future generations inherit a quality environment with a fair share of the Earth's resources.

To implement sustainable energy development, leaders in various regions of the world will need energy plans based on local and regional conditions. The plans will integrate the desired end uses for energy with the energy sources that are most appropriate for a particular region and that hold potential for conservation and efficiency. Such plans will recognize that preserving resources can be profitable and that degradation of the environment and poor economic conditions go hand in hand.[16] In other words, degradation of air, water, and land resources depletes assets and ultimately will lower both the standard of living and the quality of life. A good energy plan recognizes that energy demands can be met in environmentally preferred ways and is part of an aggressive environmental policy whose goal is a quality environment for future generations. The plan should do the following:[16]

- Provide for sustainable energy development.
- Provide for aggressive energy efficiency and conservation.
- Provide for diversity and integration of energy sources.
- Develop and use the "smart grid" to optimally manage energy flow on the scale of buildings to regions.
- Provide for a balance between economic health and environmental quality.
- Use second-law efficiencies as an energy policy tool—that is, strive to achieve a good balance between the quality of an energy source and end uses for that energy.

An important element of the plan involves the energy used for automobiles. This builds on policies of the past 30 years to develop hybrid vehicles that use both an electric motor and an internal combustion engine, and to improve fuel technology to reduce both fuel consumption and emission of air pollutants. Finally, the plan should factor in the marketplace through pricing that reflects the economic cost of using the fuel, as well as its cost to the environment. In sum, the plan should be an integrated energy-management statement that moves toward sustainable development. Those who develop such plans recognize that a diversity of energy supplies will be necessary and that the key components are (1) improvements in energy efficiency and conservation and (2) matching energy quality to end uses.[16]

The global pattern of ever-increasing energy consumption led by the United States and other nations cannot be sustained without a new energy paradigm that includes changes in human values, not just a breakthrough in technology. Choosing to own lighter, more fuel-efficient automobiles and living in more energy-efficient homes is consistent with a sustainable energy system that focuses on providing and using energy to improve human welfare. A sustainable energy paradigm establishes and maintains multiple linkages among energy production, energy consumption, human well-being, and environmental quality.[17] It might also involve using smaller generating facilities that are more widely distributed (see A Closer Look 14.2).

## A CLOSER LOOK 14.2

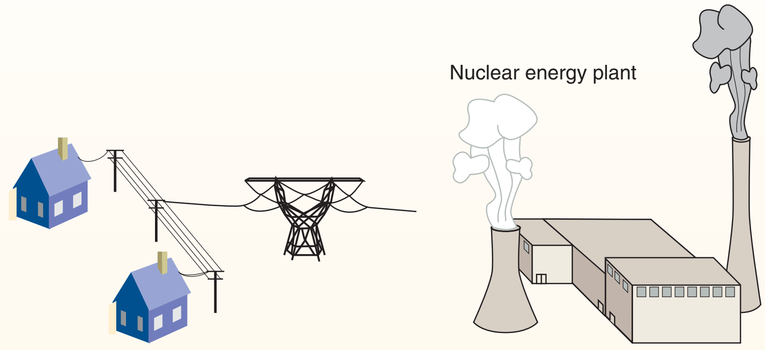
## Micropower

It is likely that sustainable energy management will include the emerging concept of **micropower**—smaller, distributed systems for production of electricity. Such systems are not new; the inventor Thomas Edison evidently anticipated that electricity-generating systems would be dispersed. By the late 1890s, many small electrical companies were marketing and building power plants, often located in the basements of businesses and factories. These early plants evidently used cogeneration principles, since waste heat was reused for heating buildings.[18] Imagine if we had followed this early model: Homes would have their own power systems, power lines wouldn't snake through our neighborhoods, and we could replace older, less efficient systems as we do refrigerators.

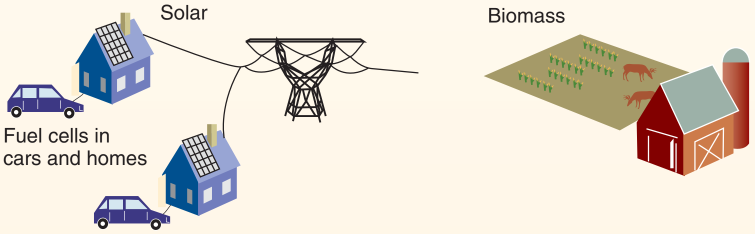
Instead, in the 20th century U.S. power plants grew larger. By the 1930s, industrializing countries had set up utility systems based on large-scale central power plants, as diagrammed in Figure 14.7a. Today, however, we are again evaluating the merits of distributive power systems, as shown in Figure 14.7b.

Large, centralized power systems are consistent with the hard path, while the distributive power system is more aligned with the soft path. Micropower devices rely heavily on renewable energy sources such as wind and sunlight, which feed into the electric grid system, as shown in Figure 14.7b. Use of micropower systems in the future is being encouraged because they are reliable and are associated with less environmental damage than are large fossil-fuel-burning power plants.[18]

Uses for micropower are emerging in both developed and developing countries. In countries that lack a centralized power-generating capacity, small-scale electrical power generation from solar and wind has become the most economical option. In nations with a high degree of industrialization, micropower may emerge as a potential replacement for aging electric power plants. For micropower to be a significant factor in energy production, a shift in policies and regulations to allow micropower devices to be more competitive with centralized generation of electrical power will be required. Regardless of the obstacles that micropower devices face, distributive power systems will probably play an important role in achieving our goal of integrated, sustainable energy management for the future.



(a) Central power plant, fossil fuel or nuclear



(b) Distributive power systems, solar, fuel cell, wind, or biomass

FIGURE 14.7 Idealized diagram comparing **(a)** a centralized power system, such as those used in industrial developed countries today, with **(b)** a distributive power system based on generating electricity from biomass, wind, solar, and other sources, all of which feed into the transmission and distribution system. (*Source*: Modified from S. Dunn, *Micropower, the Next Electrical Era*, Worldwatch Paper 151 [Washington, DC: Worldwatch Institute, 2000].)

# CRITICAL THINKING ISSUE

## Use of Energy Today and in 2030

*Note: Before proceeding with this exercise, refer back to A Closer Look 4.1 to be sure you are comfortable with the units and big numbers.*

The Organization for Economic Cooperation and Development (OECD) is a group of 30 countries, 27 of which are classified by the World Bank as having high-income economies. Non-OECD members are not all low-income countries, but many are. The developing countries (all of which are non-OECD) have most of the world's 6.8 billion people and are growing in population faster than the more affluent countries. The average rate of energy use in 2010 for an individual in non-OECD countries is 46 billion joules per person per year (1.5 kW per person), whereas for the OECD countries it is 210 billion joules per person per year (6.7 kW per person). In other words, people in OECD countries use about 4.5 times more energy per person than those in non-OECD countries. In 2010 each group—OECD and non-OECD—used about 250 EJ (1 EJ is $10^{18}$ J). The world average is 74 billion joules per person per year (2.3 kW per person).[19]

If the current annual population growth rate of 1.1% continues, the world's population will double in 64 years. However, as we learned in Chapters 1 and 4, the human population may not double again. It is expected to be about 8.5 billion by 2030. More people will likely mean more energy use. People in non-OECD countries will need to consume more energy per capita if the less developed countries are to achieve a higher standard of living; thus, energy consumption in non-OECD countries as a group is projected to increase by 2030 to about 55 billion joules per person per year (1.7 kW per person). On the other hand, energy use in OECD countries is projected to decline to about 203 billion joules per person per year (6.4 kW per person). This would bring the global average in 2030 to about 80 billion joules per person per year (2.5 kW per person), up from 74 billion joules in 2010. If these projections are correct, 58% of the energy will be consumed in the non-OECD countries, compared with 50% today.

With worldwide average energy use of 2.3 kW per person in 2010, the 6.8 billion people on Earth use about 16 trillion watts annually. A projected population of 8.5 billion in 2030 with an estimated average per capita energy use rate of 2.5 kW would use about 21 trillion watts annually, an increase of about 33% from today.[19]

A realistic goal is for annual per capita energy use to remain about 2.5 kW, with the world population peaking at 8.5 billion people by the year 2030. If this goal is to be achieved, non-OECD countries will be able to increase their populations by no more than about 50% and their energy use by about 70%; OECD nations can increase their population by only a few percent and will have to reduce their energy use slightly.

### Critical Thinking Questions

1. Using only the data presented in this exercise, how much energy, in exajoules, did the world use in 2010 and what would you project global energy use to be in 2030?
2. The average person emits as heat 100 watts of power (the same as a 100 W bulb). If we assume that 25% of it is emitted by the brain, how much energy does your brain emit as heat in a year? Calculate this in joules and kWh. What is the corresponding value for all people today, and how does that value compare with world energy use per year? Can this help explain why a large, crowded lecture hall (independent of the professor pontificating) might get warm over an hour?
3. Can the world supply one-third more energy by 2030 without unacceptable environmental damage? How?
4. What would the rate of energy use be if all people on Earth had a standard of living supported by energy use of 10 kW per person, as in the United States today? How do these totals compare with the present energy-use rate worldwide?
5. In what specific ways could energy be used more efficiently in the United States? Make a list of the ways and compare your list with those of your classmates. Then compile a class list.
6. In addition to increasing efficiency, what other changes in energy consumption might be required to provide an average energy-use rate in 2030 of 6.4 kW per person in OECD countries?
7. Would you view the energy future in 2030 as a continuation of the business-as-usual approach with more large, centralized energy production based on fossil fuels, or a softer path, with more use of alternative, distributed energy sources? Justify your view.

# SUMMARY

- The first law of thermodynamics states that energy is neither created nor destroyed but is always conserved and is transformed from one kind to another. We use the first law to keep track of the quantity of energy.
- The second law of thermodynamics tells us that as energy is used, it always goes from a more usable (higher-quality) form to a less usable (lower-quality) form.

- Two fundamental types of energy efficiency are derived from the first and second laws of thermodynamics. In the United States today, first-law efficiencies average about 50%, which means that about 50% of the energy produced is returned to the environment as waste heat. Second-law efficiencies average 10–15%, so there is a high potential for saving energy through better matching of the quality of energy sources with their end uses.
- Energy conservation and improvements in energy efficiency can have significant effects on energy consumption. It takes three units of a fuel such as oil to produce one unit of electricity. As a result, each unit of electricity conserved or saved through improved efficiency saves three units of fuel.
- There are arguments for both the business-as-usual path and changing to a new path. The first path has a long history of success and has produced the highest standard of living ever experienced. However, present sources of energy (based on fossil fuels) are causing serious environmental degradation and are not sustainable (especially with respect to conventional oil). A second path, based on alternative energy sources that are renewable, decentralized, diverse, and flexible, provides a better match between energy quality and end use, and emphasizes second-law efficiencies.
- The transition from fossil fuels to other energy sources requires sustainable, integrated energy management. The goal is to provide reliable sources of energy that do not cause serious harm to the environment and ensure that future generations will inherit a quality environment.

## REEXAMINING THEMES AND ISSUES

**Human Population**

The industrialized and urbanized countries produce and use most of the world's energy. As societies change from rural to urban, energy demands generally increase. Controlling the increase of human population is an important factor in reducing total demand for energy (total demand is the product of average demand per person and number of people).

**Sustainability**

It will be impossible to achieve sustainability in the United States if we continue with our present energy policies. The present use of fossil fuels is not sustainable. We need to rethink the sources, uses, and management of energy. Sustainability is the central issue in our decision to continue on the hard path or change to the soft path.

**Global Perspective**

Understanding global trends in energy production and consumption is important if we are to directly address the global impact of burning fossil fuels with respect to air pollution and global warming. Furthermore, the use of energy resources greatly influences global economics, as these resources are transported and utilized around the world.

**Urban World**

A great deal of the total energy demand is in urban regions, such as Tokyo, Beijing, London, New York, and Los Angeles. How we choose to manage energy in our urban regions greatly affects the quality of urban environments. Burning cleaner fuels results in far less air pollution. This has been observed in several urban regions, such as London. Burning of coal in London once caused deadly air pollution; today, natural gas and electricity heat homes, and the air is cleaner. Burning coal in Beijing continues to cause significant air pollution and health problems for millions of people living there.

**People and Nature**

Our development and use of energy are changing nature in significant ways. For example, burning fossil fuels is changing the composition of the atmosphere, particularly through the addition of carbon dioxide. The carbon dioxide is contributing to the warming of the atmosphere, water, and land (see Chapter 20 for details). A warmer Earth is, in turn, changing the climates of some regions and affecting weather patterns and the intensity of storms.

## Science and Values

Public-opinion polls consistently show that people value a quality environment. In response, energy planners are evaluating how to use our present energy resources more efficiently, practice energy conservation, and reduce adverse environmental effects of energy consumption. Science is providing options in terms of energy sources and uses; our choices will reflect our values.

## KEY TERMS

| | |
|---|---|
| cogeneration | **294** |
| conservation | **294** |
| energy efficiency | **294** |
| first-law efficiency | **290** |
| first law of thermodynamics | **289** |
| integrated energy management | **298** |
| micropower | **299** |
| second-law efficiency | **290** |
| second law of thermodynamics | **290** |
| sustainable energy development | **298** |
| work | **289** |

## STUDY QUESTIONS

1. What evidence supports the notion that, although present energy problems are not the first in human history, they are unique in other ways?
2. How do the terms *energy*, *work*, and *power* differ in meaning?
3. Compare and contrast the potential advantages and disadvantages of a major shift from hard-path to soft-path energy development.
4. You have just purchased a 100-hectare wooded island in Puget Sound. Your house is built of raw timber and is uninsulated. Although the island receives some wind, trees over 40 m tall block most of it. You have a diesel generator for electric power, and hot water is produced by an electric heater run by the generator. Oil and gas can be brought in by ship. What steps would you take in the next five years to reduce the cost of the energy you use with the least damage to the island's natural environment?
5. How might better matching of end uses with potential sources yield improvements in energy efficiency?
6. Complete an energy audit of the building you live in, then develop recommendations that might lead to lower utility bills.
7. How might plans using the concept of integrated energy management differ for the Los Angeles area and the New York City area? How might both of these plans differ from an energy plan for Mexico City, which is quickly becoming one of the largest urban areas in the world?
8. A recent energy scenario for the United States suggests that in the coming decades energy sources might be natural gas (10%), solar power (30%), hydropower (20%), wind power (20%), biomass (10%), and geothermal energy (10%). Do you think this is a likely scenario? What would be the major difficulties and points of resistance or controversy?

## FURTHER READING

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