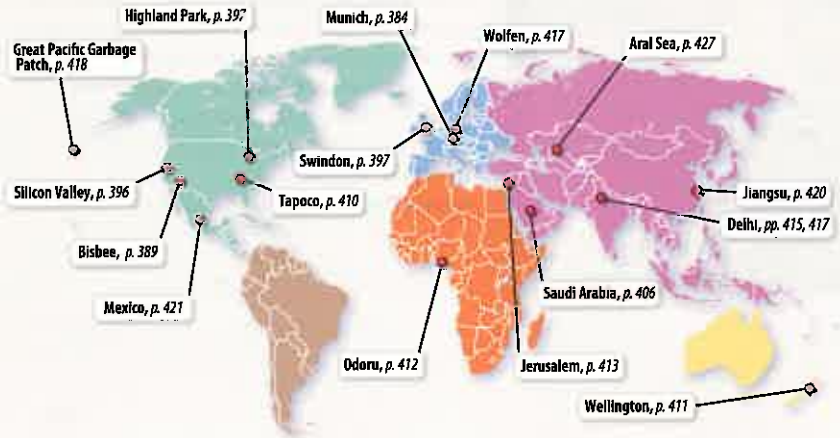
11

Industry and Energy

Industry was once highly clustered in a handful of communities within a handful of developed countries, but industry has diffused to many communities in many developing countries. Communities around the world view manufacturing jobs as a special asset, and they mourn when factories close and rejoice when they open.

Indian schoolchildren from Suraj Memorial High Senior Secondary School in Delhi, India wear oxygen masks to raise awareness regarding the dangers of air pollution.

LOCATIONS IN THIS CHAPTER



KEY ISSUES

1

Where Is Industry Distributed?

Industry is highly clustered in several ***regions***, especially North America, Europe, and East Asia.

2 Why Are Situation and Site Factors Important?

Industry is distributed in a distinctive pattern. Factors relate to a combination of the unique characteristics of a ***place*** and the ***connections*** between places.

3 Why Do Industries Face Resource Challenges?

Industries are major users of energy and major generators of pollution. Resource issues arise because the distribution of demand for them across ***space*** varies from the distribution of their supply.

4 Why Are Industries Changing Locations?

Industries are changing locations at two ***scales***. Industries are growing in some developing regions, and they are growing within developed regions in nontraditional locations.

KEY ISSUE 1

Where Is Industry Distributed?

- Introducing Industry and Energy
- Industrial Regions

LEARNING OUTCOME 11.1.1

Understand the causes of the Industrial Revolution.

The title of this chapter refers to the manufacturing of goods in a factory. The word *industry* is appropriate because it also means *persistence* or *diligence* in creating value. A factory utilizes a large number of people as well as considerable machinery and money to turn out valuable products.

Introducing Industry and Energy

The hearth of modern industry—meaning the manufacturing of goods in a factory—was in northern England and southern Scotland during the second half of the eighteenth century. From that hearth, industry diffused to Europe and to North America in the nineteenth century and to other regions in the twentieth century.

THE INDUSTRIAL REVOLUTION

The Industrial Revolution was defined in Chapter 2 as a series of improvements in industrial technology that transformed the process of manufacturing goods. Prior to the Industrial Revolution, industry was geographically dispersed across the landscape. People made household tools and agricultural equipment in their own homes or obtained them in the local village. Home-based manufacturing was known as the **cottage industry** system.

The catalyst of the Industrial Revolution was technology, and several inventions transformed the way in which goods were manufactured. The invention most important to the development of factories was the steam engine, patented in 1769 by James Watt, a maker of mathematical instruments in Glasgow, Scotland (Figure 11-1). The large supply of steam power available from Watt's steam engines induced firms to concentrate all their process steps in one building attached to a single power source.

The revolution in industrial technology created an unprecedented expansion in productivity and resulted in substantially higher standards of living. For example, the Industrial Revolution was cited in Chapter 2 as a principal cause of population growth in stage 2 of the demographic transition. Watt's engine and other inventions enabled the United Kingdom to become the world's dominant industrial power during the nineteenth century.

The term *Industrial Revolution* is somewhat misleading:

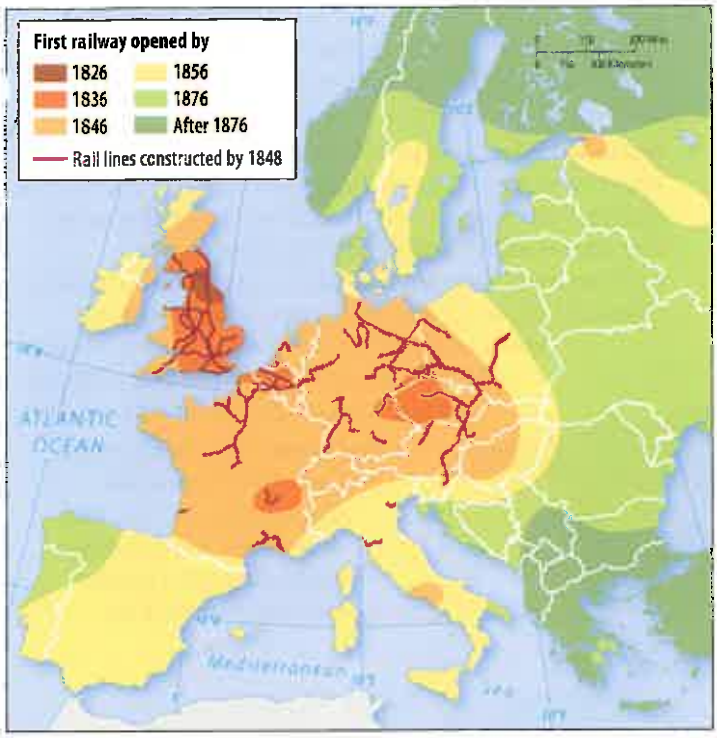
- The transformation was far more than industrial; it resulted in new social, economic, and political inventions, not just industrial ones.
- The changes involved a gradual diffusion of new ideas and techniques over decades rather than an instantaneous revolution.

Nonetheless, the term is commonly used to define the process that began in the United Kingdom in the late 1700s.

Among the first industries impacted by the Industrial Revolution were:

- **Iron.** The first industry to benefit from Watt's steam engine was the iron tool industry. The usefulness of iron had been known for centuries, but it was difficult to produce because ovens had to be constantly heated, which was difficult before the steam engine.
- **Transportation.** First canals and then railroads enabled factories to attract large numbers of workers, bring in bulky raw materials such as iron ore and coal, and ship finished goods to consumers (Figure 11-2).
- **Textiles.** Textile production was transformed from a dispersed cottage industry to a concentrated factory system during the late eighteenth century. In 1768, Richard Arkwright, a barber and wigmaker in Preston, England, invented machines to untangle cotton prior to spinning. Too large to fit inside a cottage, spinning frames were placed inside factories near sources of rapidly flowing water, which supplied the power.

▼ **FIGURE 11-1 JAMES WATT'S STEAM ENGINE** Watt built the first useful steam engine, which could pump water far more efficiently than the watermills then in common use, let alone human or animal power. Steam injected in the cylinder pushes a piston attached to a crankshaft (top of the engine) that turns the large wheel (right side of the engine), which in turn drives machinery. This Watt steam engine is on display in the Deutsches Museum in Munich, Germany.



▲ **FIGURE 11-2 DIFFUSION OF THE INDUSTRIAL REVOLUTION** The construction of railroads in the United Kingdom and on the European continent reflects the diffusion of the Industrial Revolution. Europe's political problems impeded the diffusion of the railroad. Cooperation among small neighboring states was essential to build an efficient rail network and to raise money for constructing and operating the system. Because such cooperation could not be attained, railroads in some parts of Europe were delayed 50 years after their debut in the U.K.

- **Chemicals.** The chemical industry was created to bleach and dye cloth. In 1746, John Roebuck and Samuel Garbett established a factory to bleach cotton with sulfuric acid obtained from burning coal. When combined with various metals, sulfuric acid produced another acid called vitriol, which was useful for dying clothing.
- **Food processing.** In 1810, French confectioner Nicolas Appert started canning food in glass bottles sterilized in boiling water. Canned food was essential to feed the factory workers who no longer lived on farms.

FOSSIL FUELS

Manufacturing depends on the availability of abundant low-cost energy. Developed countries use large quantities of energy to run factories, as well as to produce food, keep homes comfortable, and transport people and goods. Developing countries expect to use more energy to improve the lives of their citizens.

Historically, people relied primarily on **animate power,** which is power supplied by animals or by people themselves. Animate power was supplemented by **biomass fuel** (such as wood, plant material, and animal waste), which is burned directly or converted to charcoal, alcohol, or methane gas. Biomass remains an important source of fuel in some developing countries, but during the past 200 years, developed countries have converted primarily to energy from fossil fuels.

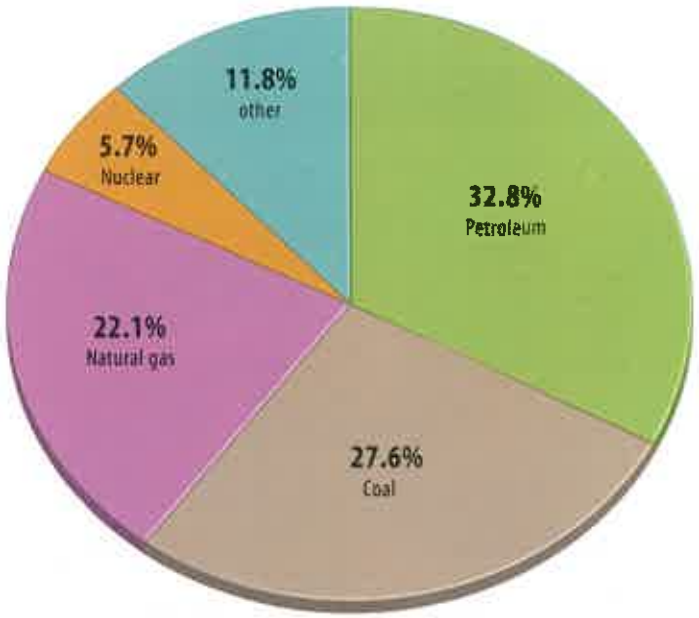
A **fossil fuel** is an energy source formed from the residue of plants and animals buried millions of years ago. As sediment accumulated over these remains, intense pressure and chemical reactions slowly converted them into the fossil fuels that are currently used. When these substances are burned, energy that was stored in plants and animals millions of years ago is released. Five-sixths of the world's energy needs are supplied by three fossil fuels (Figure 11-3):

- **Coal.** As North America and Europe developed rapidly in the late 1800s, coal supplanted wood as the leading energy source in these regions.
- **Petroleum.** First pumped in 1859, petroleum did not become an important source of energy until the diffusion of motor vehicles in the twentieth century.
- **Natural gas.** Originally burned off as a waste product of petroleum drilling, natural gas is now used to heat homes and to produce electricity.

In Chapter 1, we distinguished between renewable resources (those produced in nature more rapidly than they are consumed by humans) and nonrenewable resources (those produced in nature more slowly than they are consumed by humans). Because the fossil fuels are nonrenewable, sustainable development will necessitate increased reliance in the future on renewable energy instead of fossil fuels.

PAUSE & REFLECT 11.1.1

The use of one of the three fossil fuels is increasing in the United States in the twenty-first century. Which one is it? Why might that be the case?



▲ **FIGURE 11-3 FOSSIL FUEL DEMAND** Petroleum, coal, and natural gas account for most of the world's energy consumption.

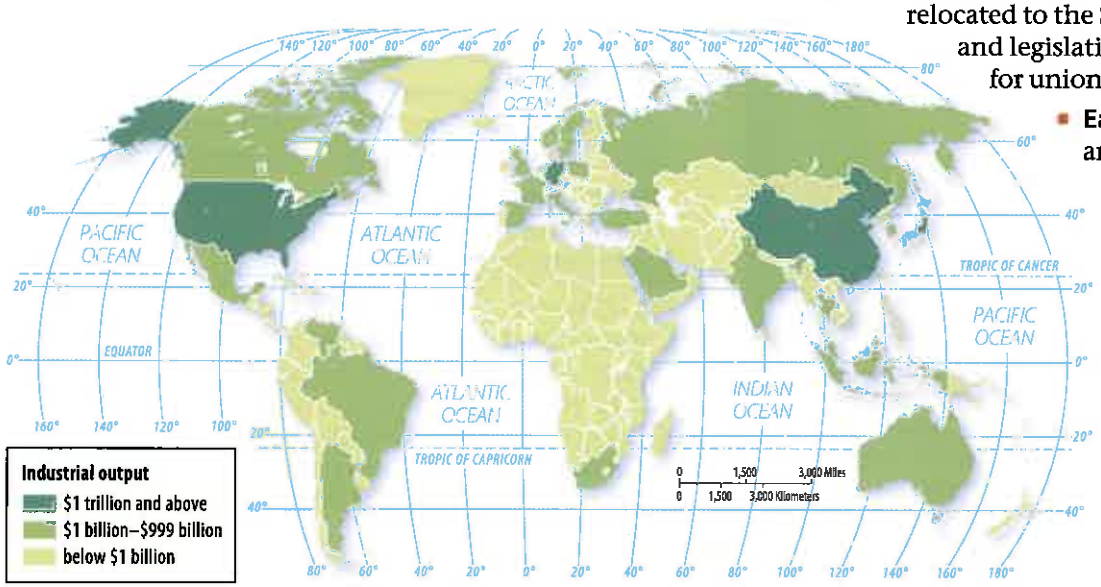
Industrial Regions

LEARNING OUTCOME 11.1.2

Describe the locations of the three principal industrial regions.

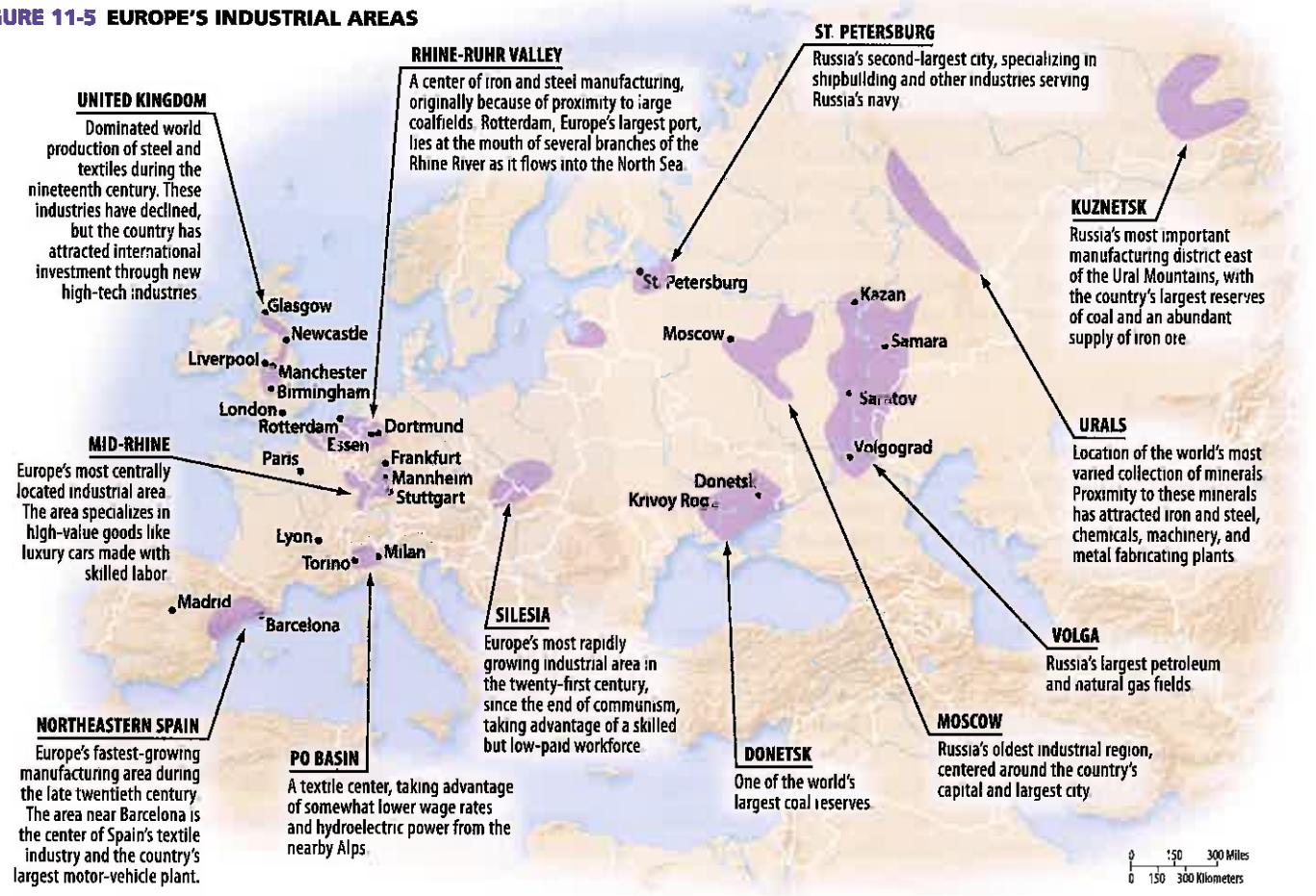
Industry is not distributed uniformly around the world (Figure 11-4). Rather, it is concentrated in three of the nine world regions discussed in Chapter 10:

- **Europe.** Europe was the first region to industrialize, during the nineteenth century. Numerous industrial centers emerged in Europe as countries competed with each other for supremacy (Figure 11-5).
- **North America.** Industry arrived a bit later in North America than in Europe, but it grew much faster in the nineteenth century. North America's manufacturing was traditionally highly concentrated in the northeastern United States and southeastern Canada (Figure 11-6). In recent years, manufacturing has relocated to the South, lured by lower wages and legislation that has made it difficult for unions to organize factory workers.
- **East Asia.** East Asia became an important industrial region in the second half of the twentieth century, beginning with Japan. Into the twenty-first



◀ **FIGURE 11-4 INDUSTRIAL OUTPUT** One-half of the world's industrial output is clustered in China, the United States, Japan, and Germany.

▼ **FIGURE 11-5 EUROPE'S INDUSTRIAL AREAS**



century, China has emerged as the world's leading manufacturing country by most measures (Figure 11-7).

Four countries account for one-half of the world's industrial output: China, the United States, Japan, and Germany.

PAUSE & REFLECT 11.1.2

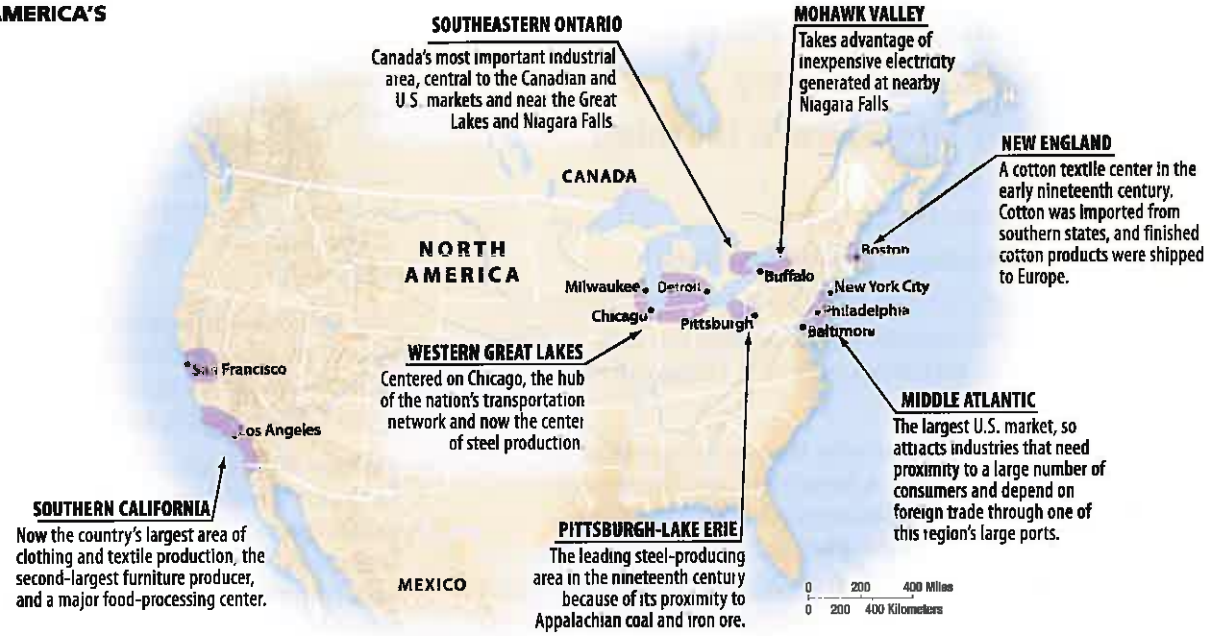
Compare the world's principal industrial areas with population distribution (Figure 2-4). Are industrial areas generally in regions of high population density or low? Why?

CHECK-IN KEY ISSUE 1

Where Is Industry Distributed?

- ✔ **The Industrial Revolution involved a series of improvements that transformed manufacturing. Most of the improvements occurred first in the United Kingdom.**
- ✔ **Industry depends on access to abundant and affordable suppliers of fossil fuels.**
- ✔ **The world's three principal industrial regions are Europe, North America, and East Asia.**

▶ **FIGURE 11-6 NORTH AMERICA'S INDUSTRIAL REGIONS**



◀ **FIGURE 11-7 EAST ASIA'S INDUSTRIAL REGIONS**

KEY ISSUE 2

Why Are Situation and Site Factors Important?

- Situation Factors: Proximity to Inputs
- Situation Factors: Proximity to Markets
- Changing Situation Factors: Steel
- Truck, Train, Ship, or Plane?
- Site Factors in Industry
- Changing Site Factors: Clothing

LEARNING OUTCOME 11.2.1

Identify the two types of situation factors.

Geographers try to explain why one location may be more profitable for a factory than others. A company ordinarily faces two geographic costs:

- **Situation factors** involve transporting materials to and from a factory. A firm seeks a location that minimizes the cost of transporting inputs to the factory and finished goods to consumers.
- **Site factors** result from the unique characteristics of a location. These are labor, capital, and land.

Situation Factors: Proximity to Inputs

Manufacturers buy from suppliers of inputs, such as minerals, materials, energy, machinery, and supporting services. They sell to companies and individuals who purchase the products. The farther something is transported, the higher the cost, so a manufacturer tries to locate its factory as close as possible to its inputs and markets:

- **Proximity to inputs.** The optimal plant location is as close as possible to inputs if the cost of transporting raw materials to the factory is greater than the cost of transporting the product to consumers.
- **Proximity to markets.** The optimal plant location is as close as possible to the customer if the cost of transporting raw materials to the factory is less than the cost of transporting the product to consumers.

MINERAL RESOURCES

Minerals are especially important inputs for many industries. Earth has 92 natural elements, but about 99 percent of the crust is composed of 8 of them (Figure 11-8). The 8 most common elements combine with thousands of rare ones to form approximately 3,000 different minerals, all with their own properties of hardness, color, and density, as well as spatial distribution. Many of these minerals have important industrial uses.

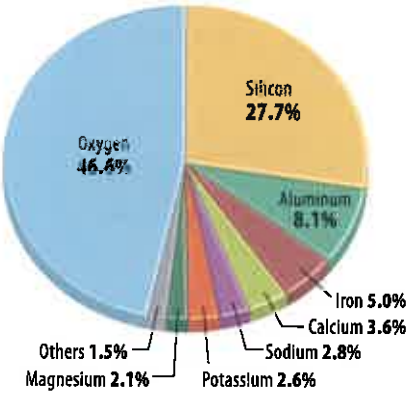
Minerals are either nonmetallic or metallic:

- **Nonmetallic minerals.** By weight, more than 90 percent of the minerals that humans use are nonmetallic. Important nonmetallic minerals include building stones, gemstones such as diamonds, and minerals used in the manufacture of fertilizers such as nitrogen, phosphorus, potassium, calcium, and sulfur.
- **Metallic minerals.** Metallic minerals have properties that are especially valuable for fashioning machinery, vehicles, and other essential elements of contemporary society. They are to varying degrees malleable (able to be hammered into thin plates) and ductile (able to be drawn into fine wire) and are good conductors of heat and electricity.

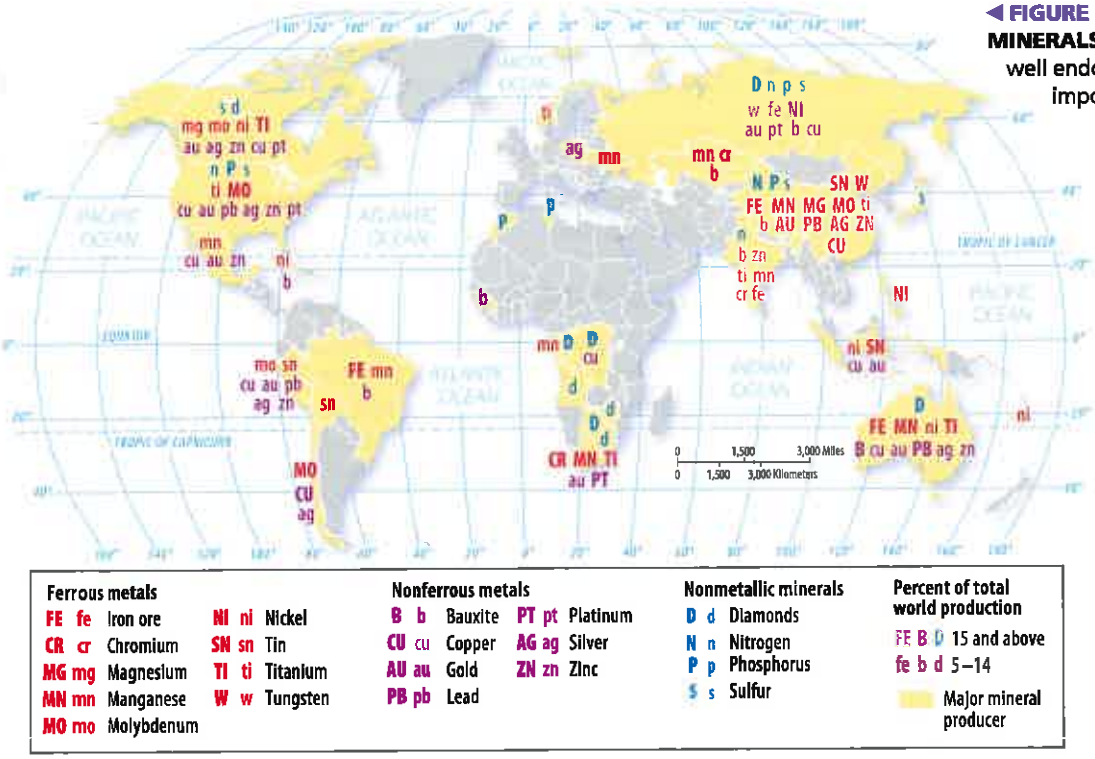
Many metals are capable of combining with other metals to form alloys with distinctive properties that are important for industry. Alloys are known as ferrous or nonferrous. A ferrous alloy contains iron, and a nonferrous one does not:

- **Ferrous alloys.** The word *ferrous* comes from the Latin for "iron." Iron is extracted from iron ore, by far the world's most widely used ore. Humans began fashioning tools and weapons from iron 4,000 years ago. Important metals used to make ferrous alloys include chromium, manganese, molybdenum, nickel, tin, titanium, and tungsten.
- **Nonferrous alloys.** Important metals utilized to manufacture products that don't contain iron and steel include aluminum, copper, lead, lithium, magnesium, zinc, precious metals (silver, gold, and the platinum group), and rare earth metals.

Mineral resources are not distributed uniformly across Earth. Countries with important mineral resources are shown in orange in Figure 11-9. Few important minerals are found in Europe, Central Asia, and Southwest Asia & North Africa.



◀ **FIGURE 11-8 ELEMENTS IN EARTH'S CRUST**



◀ **FIGURE 11-9 DISTRIBUTION OF MINERALS** Australia and China are especially well endowed with minerals that are important for industry.

4. **Refining.** The purified copper produced by smelters is treated at refineries to produce copper cathodes, about 99.99 percent pure copper. Most refineries are located near smelters.
5. **Manufacturing.** Copper that is ready for use in other products is produced in foundries.

Figure 11-11 shows the distribution of the U.S. copper industry. Mining, concentration, smelting, and refining are bulk-reducing industries; because two-thirds of U.S. copper is mined in Arizona, the state also has most of the concentration mills, smelters, and refineries. The first four steps are good examples of bulk-reducing activities that need to be located near their sources of inputs. The fifth step—manufacturing—is not bulk reducing, so foundries are located near markets on the East and West coasts rather than near inputs.

PROXIMITY TO INPUTS: COPPER INDUSTRY

An industry in which the inputs weigh more than the final products is a **bulk-reducing industry.** To minimize transport costs, a bulk-reducing industry locates near its sources of inputs. An example of a bulk-reducing industry is most of the steps of copper production.

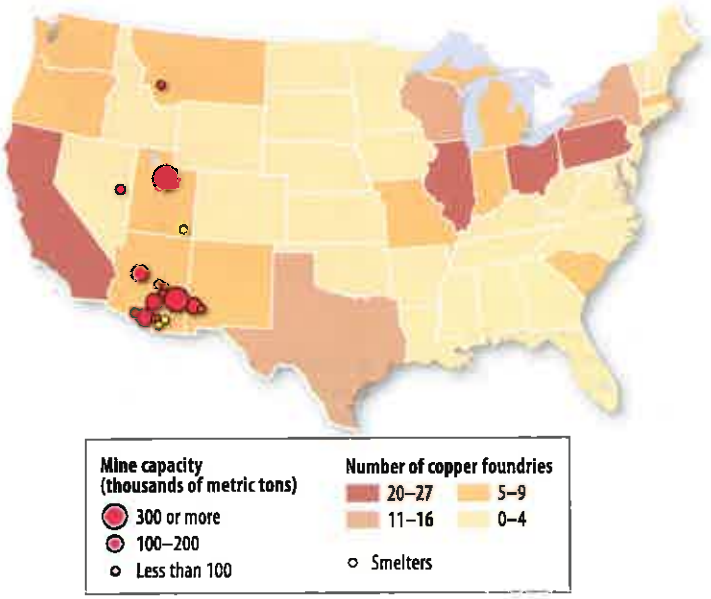
Copper production involves several steps:

1. **Mining.** Mining in general is bulk reducing because the heavy, bulky ore extracted from mines is mostly waste, known as gangue (Figure 11-10).
2. **Concentration.** The ore is crushed and ground into fine particles, mixed with water and chemicals, filtered, and dried. Concentration mills are near copper mines because concentration transforms the heavy, bulky copper ore into a product of much higher value per weight.
3. **Smelting.** The concentrated copper becomes the input for smelters, which remove more impurities. Because smelting is a bulk-reducing industry, smelters are built near their main inputs—the concentration mills—again to minimize transportation costs.

▼ **FIGURE 11-10 COPPER MINE** Bisbee, Arizona.

PAUSE & REFLECT 11.2.1

What is an example of a product purchased by consumers that is made of copper?



▲ **FIGURE 11-11 DISTRIBUTION OF COPPER PRODUCTION**

Situation Factors: Proximity to Markets

LEARNING OUTCOME 11.2.2

Explain why some industries locate near markets.

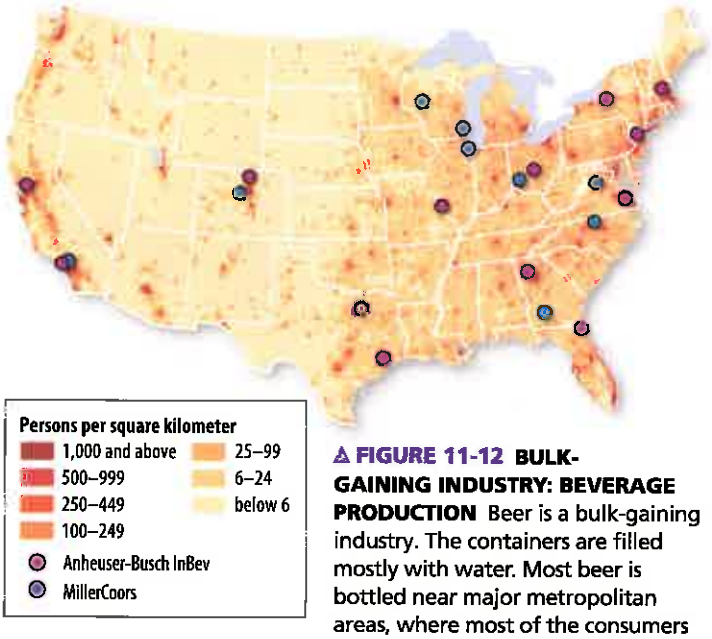
For many firms, the optimal location is close to customers. Proximity to markets is a critical locational factor for three types of industries: bulk-gaining industries, single-market manufacturers, and perishable-products companies.

BULK-GAINING INDUSTRIES

A **bulk-gaining industry** makes something that gains volume or weight during production. To minimize transport costs, a bulk-gaining industry needs to locate near where the product is sold.

A prominent example of a bulk-gaining industry is the fabrication of parts and machinery from steel and other metals. A fabricated-metal factory brings together metals such as steel and previously manufactured parts as the main inputs and transforms them into a more complex product. Fabricators shape individual pieces of metal using such processes as bending, forging (hammering or rolling metal between two dies), stamping (pressing metal between two dies), and forming (pressing metal against one die). Separate parts are joined together through welding, bonding, and fastening with bolts and rivets.

Beverage bottling is another good example of a bulk-gaining industry. In this case, the product gains weight (Figure 11-12). Because water is the principal ingredient in beer or cola, a filled container is much heavier than an empty one. Shipping filled containers is more expensive than shipping empty ones, so to minimize shipping costs, bottlers locate near their customers rather than the manufacturers of the containers.



▲ FIGURE 11-12 BULK-GAINING INDUSTRY: BEVERAGE PRODUCTION Beer is a bulk-gaining industry. The containers are filled mostly with water. Most beer is bottled near major metropolitan areas, where most of the consumers are clustered. The areas in color on the map have relatively high population density.

PAUSE & REFLECT 11.2.2

Why isn't wine bottled near the market, as beer and cola are?

SINGLE-MARKET MANUFACTURERS

A single-market manufacturer is a specialized manufacturer with only one or two customers. The optimal location for these factories is often in close proximity to the customers.

An example of a single-market manufacturer is a producer of buttons, zippers, clips, pins, or other specialized components attached to clothing. The clothing manufacturer may need additional supplies of these pieces on very short notice. The world's largest manufacturer of zippers, YKK, for example, has factories in 68 countries in order to be near its customers, the manufacturers of clothing.

The makers of parts for motor vehicles are another example of specialized manufacturers with only one or two customers—the major motor vehicle producers, such as GM and Toyota. Carmakers' assembly plants account for only around 30 percent of the value of the vehicles that bear their names. Independent parts makers supply the other 70 percent of the value. In the past, most motor vehicle parts were made in Michigan and shipped to nearby warehouses and distribution centers maintained in that state by the major producers. From the warehouses, the producers sent the parts to plants around the country where the vehicles were assembled. Parts makers now ship most of their products directly to assembly plants and are therefore more likely than in the past to cluster near the final assembly plants.

PERISHABLE-PRODUCTS COMPANIES

To deliver their products to consumers as rapidly as possible, perishable-products industries must be located near their markets. Because few people want stale bread or sour milk, food producers such as bakers and milk bottlers must locate near their customers to assure rapid delivery. Processors of fresh food into frozen, canned, and preserved products can, however, locate far from their customers. Cheese and butter, for example, are manufactured in Wisconsin because rapid delivery to the urban markets is not critical for products with a long shelf life, and the area is well suited agriculturally for raising dairy cows.

MOTOR VEHICLE PRODUCTION AND SALES

The motor vehicle is a prominent example of a fabricated metal product that is likely to be built near its market. Around 90 million new vehicles are sold annually worldwide. China accounts for 27 percent of those sales, other

▲ **FIGURE 11-13 MOTOR VEHICLE SALES** China, the rest of Asia, North America, and Europe account for nearly 90 percent of world vehicles sales.

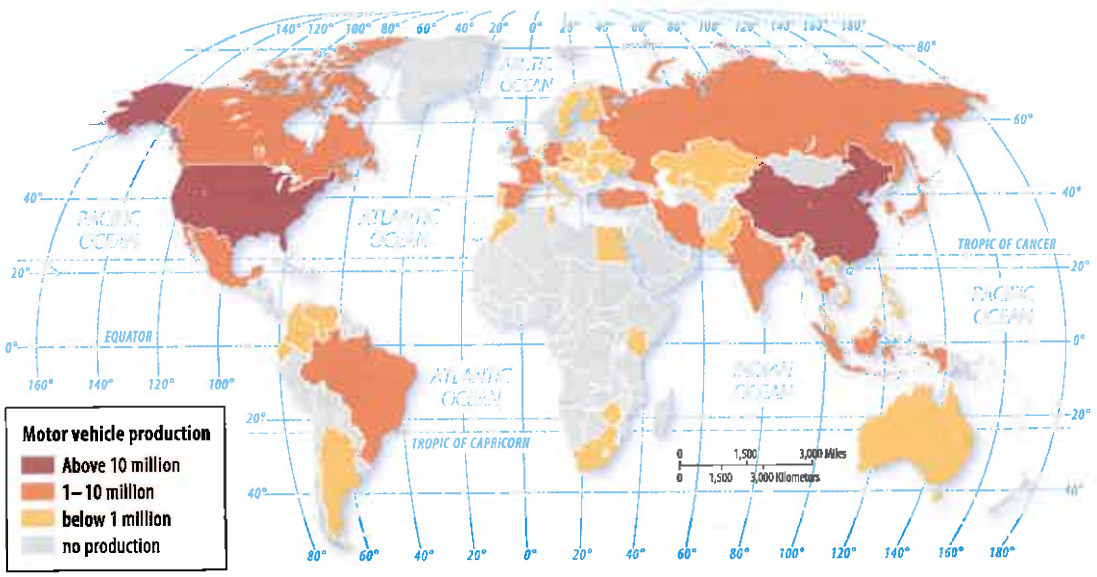
Asian countries 22 percent, North America (including Mexico) 23 percent, and Europe 17 percent (Figure 11-13).

Not surprisingly, in view of the importance of producing vehicles near their markets, the regional distribution of production is extremely close to that for sales (Figure 11-14). China and the rest of Asia each have 26 percent of world production, and Europe and North America (including Mexico) each have 19 percent. For example, around 80 percent of vehicles sold in North America are produced in North America. Around 10 percent come from Japan and 10 percent from elsewhere (Figure 11-15). Similarly, most vehicles sold in Europe are assembled in Europe, most vehicles sold in Japan are assembled in Japan, and most vehicles sold in China are assembled in China.

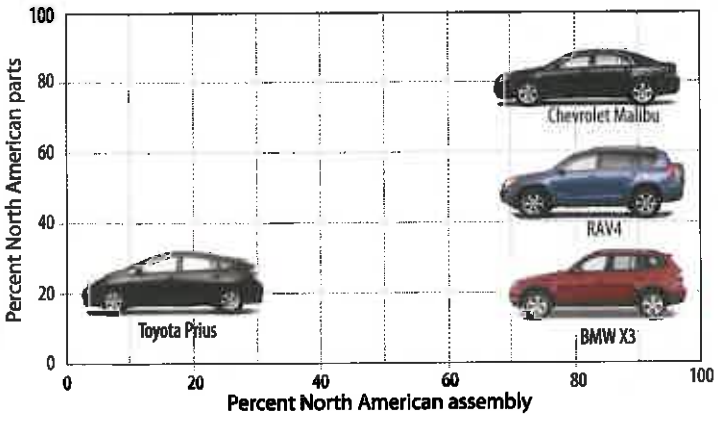
While most vehicles are produced near where they are sold, the nationality of the manufacturers is less likely to be local. Eight carmakers sold at least 4 million vehicles in 2014 and together accounted for 70 percent of the world's sales. These were:

- Two based in North America: Ford and GM.
- Three based in Europe: Germany's Volkswagen, France's Renault (which controls Nissan), and Italy's Fiat Chrysler.
- Three based in East Asia: Japan's Toyota and Honda, and South Korea's Hyundai.

These carmakers operate assembly plants in all three major industrial regions.



▶ **FIGURE 11-14 MOTOR VEHICLE PRODUCTION** The regional distribution of vehicle production closely matches the regional distribution of sales.



◀ **FIGURE 11-15 "AMERICAN" AND "FOREIGN" CARS** The x-axis shows the percentage of these vehicles sold in North America that were assembled in North America in 2015. The y-axis shows the percentage of North American parts in these vehicles.

Changing Situation Factors: Steel

LEARNING OUTCOME 11.2.3

Describe how the optimal location for steel production has changed.

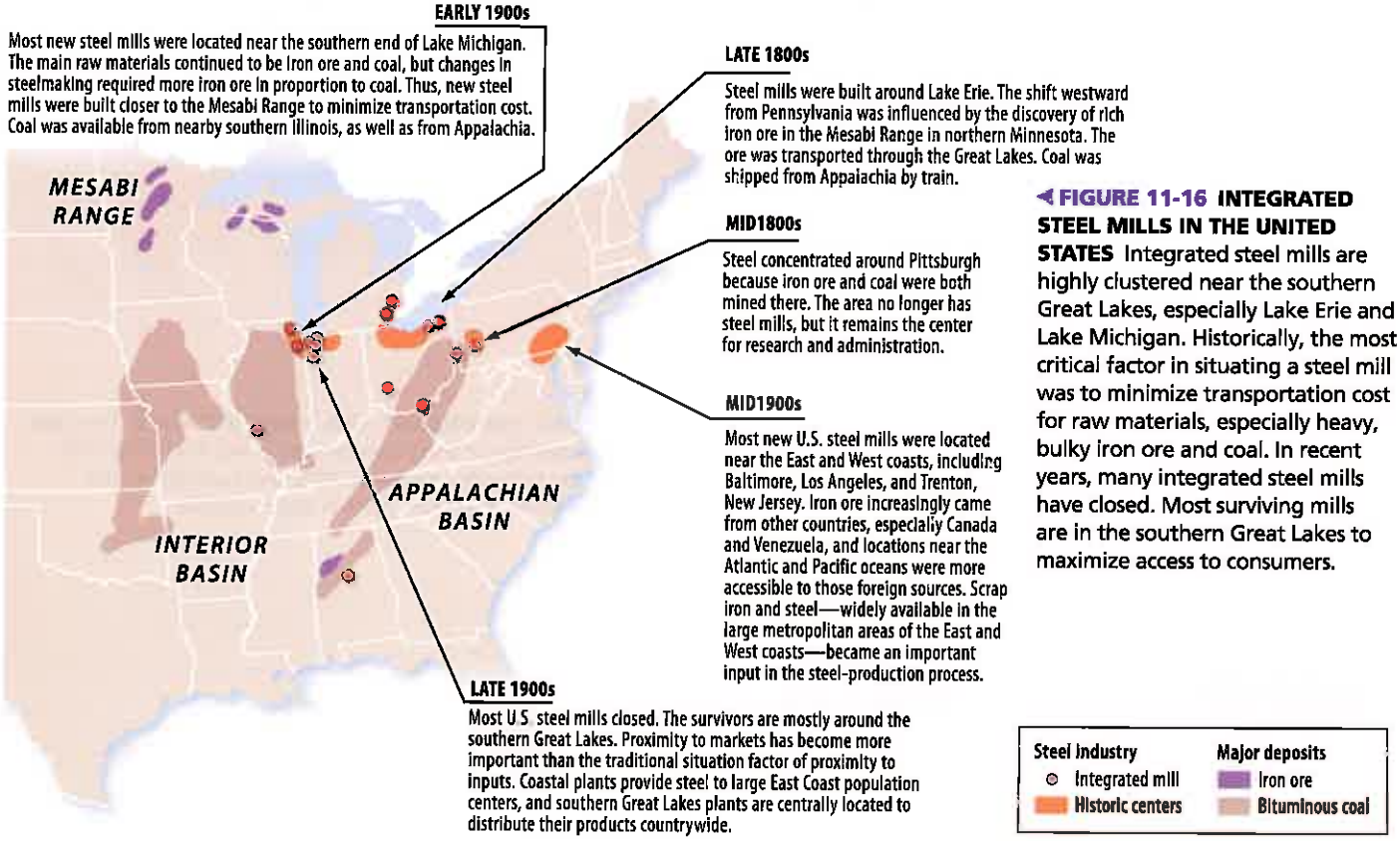
Steel is an alloy of iron that is manufactured by removing impurities in iron, such as silicon, phosphorus, sulfur, and oxygen, and adding desirable elements, such as manganese and chromium. The two principal inputs in steel production are iron ore and coal. Most steel was produced at large integrated mill complexes. They processed iron ore, converted coal into coke, converted the iron into steel, and formed the steel into sheets, beams, rods, or other shapes.

CHANGING DISTRIBUTION OF U.S. STEEL

In the past, steel production was a good example of a bulk-reducing industry that located near its inputs. Because of the need for large quantities of bulky, heavy iron ore and coal, steelmaking traditionally clustered near sources of the two key raw materials. Within the United States, the distribution of steel production has changed several times because of changing inputs. As sources and importance of these inputs changed, so did the optimal location for steel production within the United States (Figure 11-16).

More recently, steel production has relocated to be closer to markets. The increasing importance of proximity to markets is demonstrated by the recent growth of steel minimills, which have captured one-half of the U.S. steel market (Figure 11-17). Rather than iron ore and coal, scrap metal is the main input into minimill production. Minimills, generally limited to one step in the process—steel production—are less expensive to build and operate than integrated mills, and they can locate near their markets because their main input—scrap metal—is widely available.

▲ **FIGURE 11-17 MINIMILLS** Minimills, which produce steel from scrap metal, are more numerous than integrated steel mills, and they are distributed around the country near local markets. Shown are the plants of Nucor, the largest minimill operator in the United States.



◀ **FIGURE 11-16 INTEGRATED STEEL MILLS IN THE UNITED STATES** Integrated steel mills are highly clustered near the southern Great Lakes, especially Lake Erie and Lake Michigan. Historically, the most critical factor in situating a steel mill was to minimize transportation cost for raw materials, especially heavy, bulky iron ore and coal. In recent years, many integrated steel mills have closed. Most surviving mills are in the southern Great Lakes to maximize access to consumers.

PAUSE & REFLECT 11.2.3

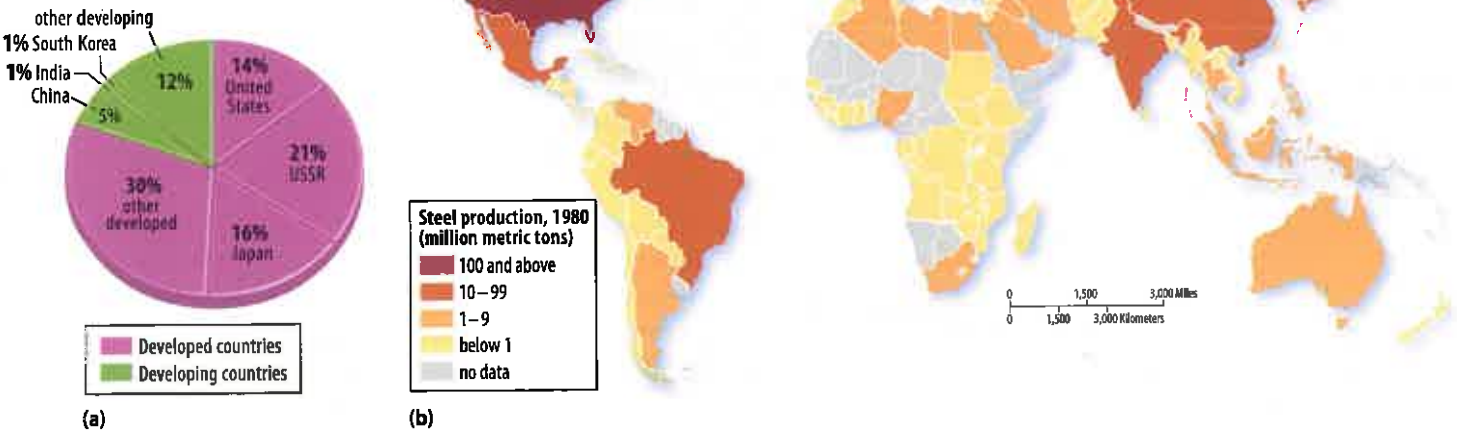
Pittsburgh's football team is named "Steelers," but based on Figure 11-16, what city's team might be a more appropriate choice for the nickname?

CHANGING DISTRIBUTION OF WORLD STEEL PRODUCTION

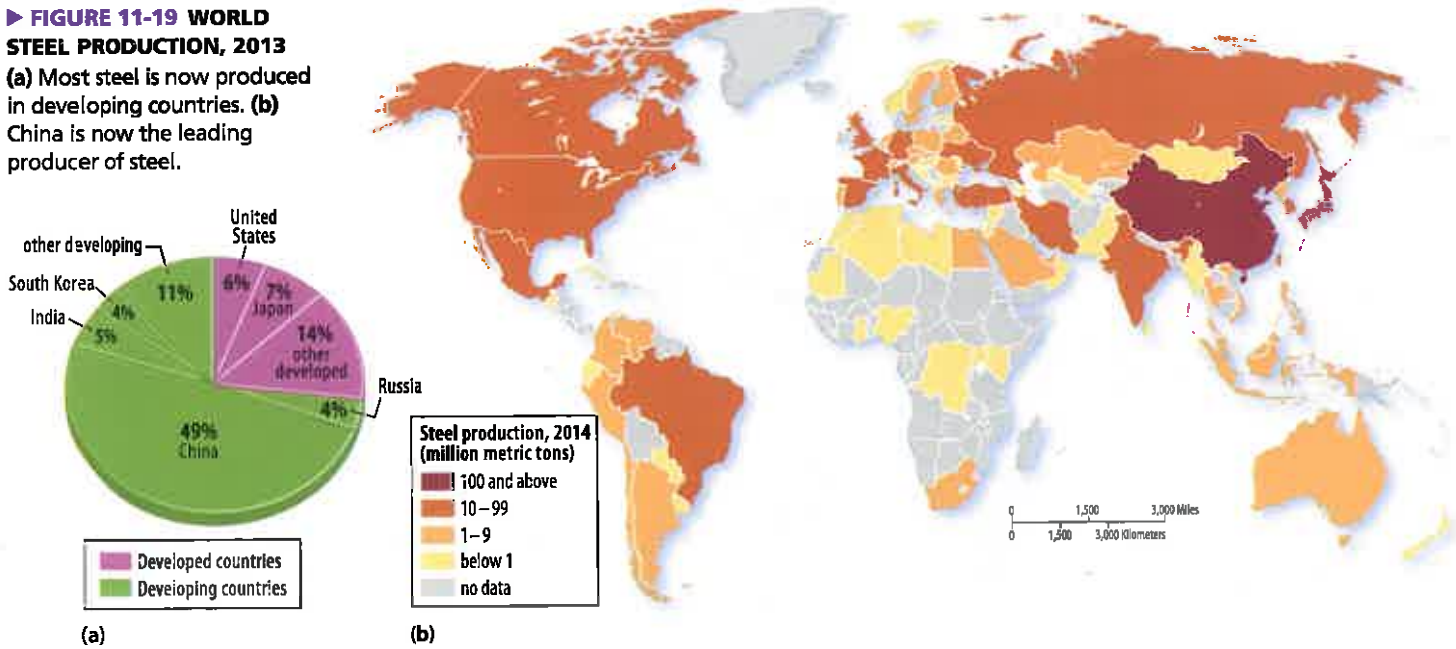
The shift of world manufacturing to new industrial regions can be seen clearly in steel production. In 1980, 81 percent of world steel was produced in developed countries and 19 percent in developing countries (Figure 11-18). Between 1980 and 2013, the share of world steel production declined to 27 percent in developed countries and increased to 73 percent in developing countries (Figure 11-19).

World steel production more than doubled between 1980 and 2013, from 0.7 billion to 1.5 billion metric tons. China was responsible for 0.7 billion of the 0.8 billion metric ton increase, and other developing countries (primarily India and South Korea) were responsible for another 0.2 billion. Production in developed countries declined by 0.1 billion metric tons. China's steel industry has grown in part because of access to the primary inputs iron ore and coal. However, the principal factor in recent years has been increased demand by growing industries in China that use a lot of steel, such as motor vehicles.

▶ FIGURE 11-18 WORLD STEEL PRODUCTION, 1980
(a) Most steel was produced in developed countries. **(b)** The United States was the leading producer in 1980.



▶ FIGURE 11-19 WORLD STEEL PRODUCTION, 2013
(a) Most steel is now produced in developing countries. **(b)** China is now the leading producer of steel.



Truck, Train, Ship, or Plane?

LEARNING OUTCOME 11.2.4

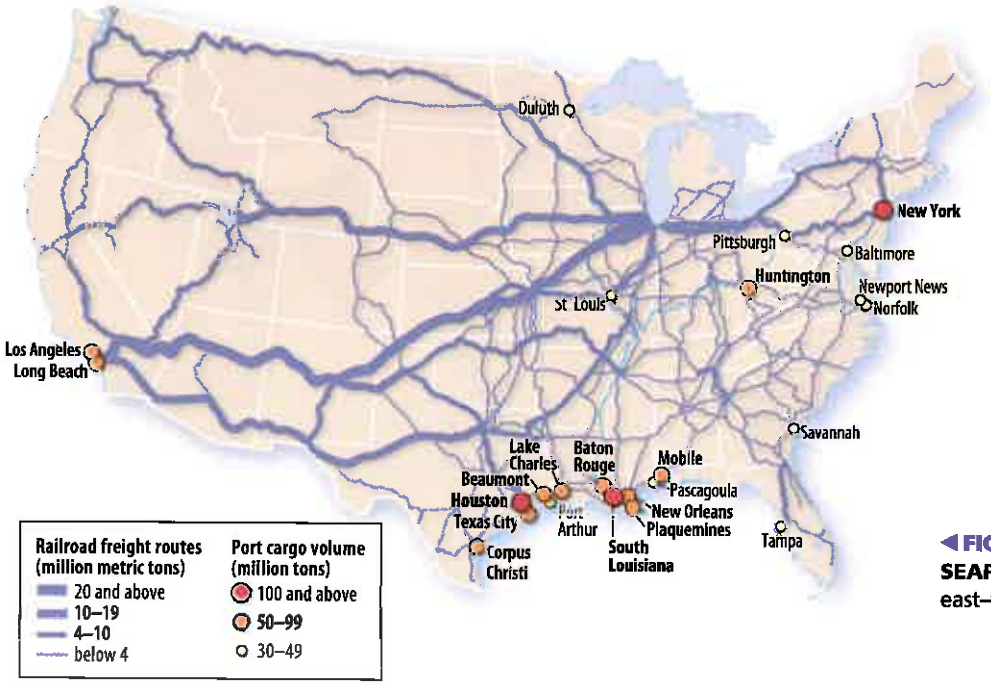
Explain why industries use different modes of transportation.

Inputs and products are transported in one of four ways: via ship, rail, truck, or air. Firms seek the lowest-cost mode of transport, but which of the four alternatives is cheapest changes with the distance that goods are being sent.

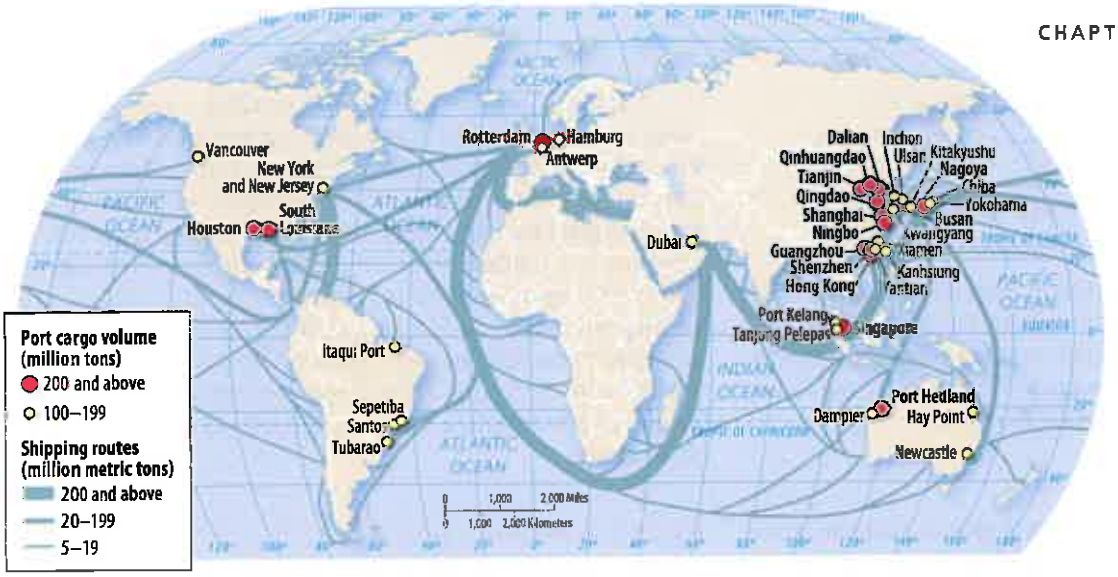
The farther something is transported, the lower the cost per kilometer (or mile). Longer-distance transportation is cheaper per kilometer in part because firms must pay workers to load goods on and off vehicles, whether the material travels 10 kilometers or 10,000. The cost per kilometer decreases at different rates for each of the four modes because the loading and unloading expenses differ for each mode:

- Trucks are most often used for short-distance delivery because they can be loaded and unloaded quickly and cheaply. Truck delivery is especially advantageous if the driver can reach the destination within one day, before having to stop for an extended rest (Figure 11-20).
- Trains are often used to ship to destinations that take longer than one day to reach, such as between the East and West coasts of the United States. Loading trains takes longer than loading trucks, but once under way, trains aren't required to make daily rest stops like trucks (Figure 11-21).

◀ **FIGURE 11-20 U.S. FREIGHT CORRIDORS** The highest volumes of freight truck traffic are in the eastern portion of the United States.



◀ **FIGURE 11-21 U.S. RAIL FREIGHT AND SEAPORTS** Most rail traffic moves long distances east–west within the United States.



◀ **FIGURE 11-22 WORLD SHIPPING ROUTES** Most freight is moved between continents by ship.

- Ships are attractive for transport over very long distances because the cost per kilometer is very low. Ships are slower than land-based transportation, but unlike trains or trucks, they can cross oceans, such as to North America from Europe or Asia (Figure 11-22).
- Airplanes are most expensive for all distances so are usually reserved for speedy delivery of small-bulk, high-value packages.

BREAK-OF-BULK POINTS

Mixed modes of delivery are often used. For example, air-freight companies pick up packages in the afternoon and transport them by truck to the nearest airport. Late at night, planes filled with packages are flown to a central hub airport in the interior of the country, such as Memphis, Tennessee, or Louisville, Kentucky. The packages are transferred to other planes, flown to airports nearest their destination, transferred to trucks, and delivered the next morning.

Many companies that use multiple transport modes locate at a **break-of-bulk point,** which is a location where transfer among transportation modes is possible. Important break-of-bulk points include seaports and airports. For example, a steel mill in Gary, Indiana, may receive iron ore by ship via Lake Michigan and coal by train from Appalachia.

Containerization has facilitated transfer of packages between modes. Containers may be packed into a rail car, transferred quickly to a container ship to cross the ocean, and unloaded onto trucks at the other end. Large ships have been specially built to accommodate large numbers of rectangular box-like containers.

Regardless of transportation mode, cost rises each time inputs or products are transferred from one mode to another. For example, workers must unload goods from a truck and then reload them onto a plane. The company may need to build or rent a warehouse to store goods temporarily after unloading from one mode and before loading to another mode. Some companies may calculate that the cost of one mode is lower for some inputs and products, whereas another mode may be cheaper for other goods.

JUST-IN-TIME DELIVERY

Proximity to market has become more important in recent years because of the rise of just-in-time delivery. As the name implies, **just-in-time delivery** is shipment of parts and materials to arrive at a factory moments before they are needed. Just-in-time delivery is especially important for delivery of inputs, such as parts and raw materials, to manufacturers of fabricated products, such as cars and computers.

Under a just-in-time system, parts and materials arrive at a factory frequently, in many cases daily or even hourly. Suppliers of the parts and materials are told a few days in advance how much will be needed over the next week or two, and first thing each morning, they are told exactly what will be needed at precisely what time that day. To meet a tight timetable, a supplier of parts and materials must locate factories near its customers. If given only an hour or two of notice, a supplier has no choice but to locate a factory within around one hour of the customer.

Just-in-time delivery reduces the money that a manufacturer must tie up in wasteful inventory. Manufacturers also save money through just-in-time delivery by reducing the size of the factory because space does not have to be wasted on piling up a mountain of inventory.

Leading computer manufacturers have eliminated inventory altogether. They build computers only in response to customer orders placed primarily over the Internet or by telephone.

Just-in-time delivery means that producers have lower inventory to cushion against disruptions in the arrival of needed parts. Three kinds of disruptions can result from reliance on just-in-time delivery:

- **Natural hazards.** Poor weather conditions can affect deliveries anywhere in the world. For example, blizzards can close highways, rail lines, and airports.
- **Traffic.** Deliveries may be delayed when traffic is slowed by accident, construction, or unusually heavy volume.
- **Labor unrest.** A strike at one supplier plant can shut down the entire production within a couple days.

PAUSE & REFLECT 11.2.4

How might weather conditions influence the choice of a factory site between the North and the South in the United States?

Site Factors in Industry

LEARNING OUTCOME 11.2.5

Understand the three types of site factors.

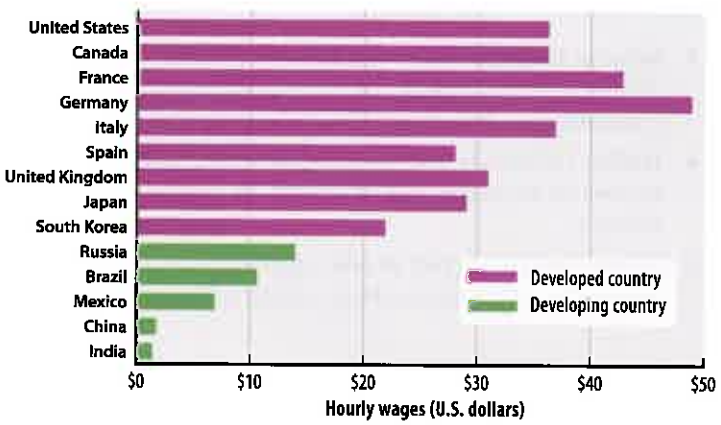
Site factors are industrial location factors related to the costs of factors of production inside a plant. For some firms, site factors are more important than situation factors in locating a factory. The three production factors that may vary among locations are labor, capital, and land.

LABOR

The most important site factor on a global scale is labor. Minimizing labor costs is important for some industries, and the variation of labor costs around the world is large. Worldwide, around one-half billion workers are engaged in industry, according to the UN International Labor Organization (ILO). China has around one-fourth of the world's manufacturing workers, India around one-fifth, and all developed countries combined around one-fifth.

A **labor-intensive industry** is an industry in which wages and other compensation paid to employees constitute a high percentage of expenses. Labor constitutes an average of 11 percent of overall manufacturing costs in the United States, so a labor-intensive industry in the United States would have a much higher percentage than that. The reverse case, an industry with a much lower-than-average percentage of expenditures on labor, is considered capital intensive.

The average wage paid to manufacturing workers is approximately $35 per hour in developed countries and exceeds $40 per hour in parts of Europe (Figure 11-23). Health-care, retirement pensions, and other benefits add substantially to the compensation. In China and India, average wages are less than $2 per hour and include limited additional benefits. For some manufacturers—but not all—the difference between paying workers $2 and $35 per hour is critical.



▲ **FIGURE 11-23 SITE FACTOR: LABOR** The chart shows average hourly wages for workers in manufacturing for 2012 in 14 of the 15 countries with the largest industrial production in 2014.

A labor-intensive industry is not the same as a high-wage industry. "Labor-intensive" is measured as a percentage, whereas "high-wage" is measured in dollars or other currencies. For example, motor-vehicle workers are paid much higher hourly wages than textile workers, yet the textile industry is labor intensive, and the auto industry is not. Although auto workers earn relatively high wages, most of the value of a car is accounted for by the parts and the machinery needed to put together the parts. On the other hand, labor accounts for a large percentage of the cost of producing a towel or shirt compared with materials and machinery.

PAUSE & REFLECT 11.2.5

Labor accounts for around 5 percent of the cost of manufacturing a car. Does this mean that motor vehicle manufacturing is a labor-intensive industry?

CAPITAL

Manufacturers typically borrow capital—the funds to establish new factories or expand existing ones. The U.S. motor-vehicle industry concentrated in Michigan early in the twentieth century largely because that region's financial institutions were more willing than eastern banks to lend money to the industry's pioneers.

The most important factor in the clustering of high-tech industries in California's Silicon Valley—even more important than proximity to skilled labor—was the availability of capital. Banks in Silicon Valley have long been willing to provide money for new software and communications firms, even though lenders elsewhere have hesitated. High-tech industries have been risky propositions—roughly two-thirds of them fail—but Silicon Valley financial institutions have continued to lend money to engineers who have good ideas so that they can buy the software, communications, and networks they need to get started (Figure 11-24). One-fourth of all capital in the United States is spent on new industries in Silicon Valley.

▼ **FIGURE 11-24 SITE FACTOR: CAPITAL** High-tech industries, such as Google, have clustered in Silicon Valley, California, primarily because of availability of capital.

The ability to borrow money has become a critical factor in the distribution of industry in developing countries. Financial institutions in many developing countries are short of funds, so new industries must seek loans from banks in developed countries. But enterprises may not get loans if they are located in a country that is perceived to have an unstable political system, a high debt level, or ill-advised economic policies.

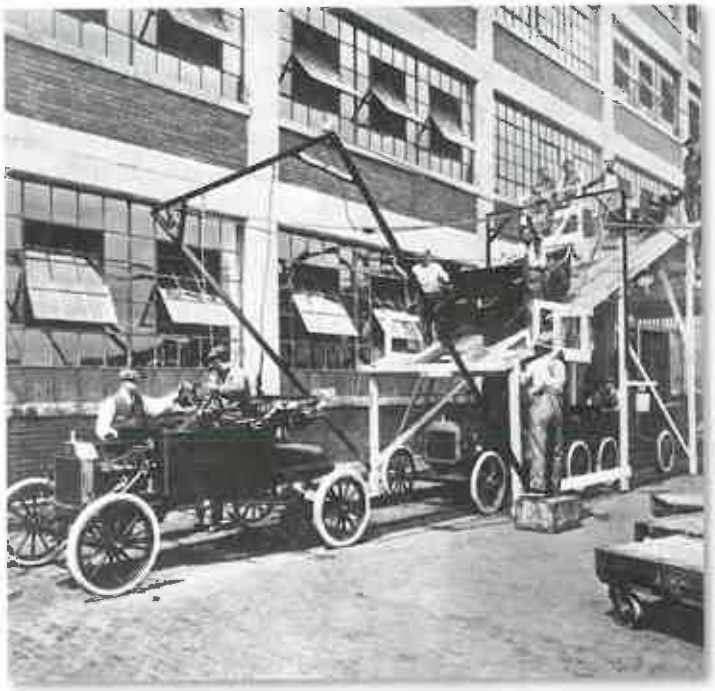
LAND

Land suitable for constructing a factory can be found in many places. If considered to encompass energy and other natural resources in addition to terra firma, "land" is an especially critical site factor. Energy inputs into production are discussed in the next section.

Early factories located inside cities due to a combination of situation and site factors. A city offered an attractive situation—proximity to a large local market and convenience in shipping to a national market by rail. A city also offered an attractive site—proximity to a large supply of labor as well as to sources of capital. The site factor that cities have always lacked is abundant land. To get the necessary space in cities, early factories were typically multistory buildings. Raw materials were hoisted to the upper floors to make smaller parts, which were then sent downstairs on chutes and pulleys for final assembly and shipment (Figure 11-25). Water was stored in tanks on the roof.

Contemporary factories operate most efficiently when laid out in one-story buildings (see, for example, Figure 11-26). Raw materials are typically delivered at one end and moved through the factory on conveyors or forklift trucks. Products are assembled in logical order and shipped out at the other end. The land needed to build one-story factories is now more likely to be available in suburban and rural locations. Also, land is much cheaper in suburban and rural locations than near the center of a city.

In addition to providing enough space for one-story buildings, locations outside cities are also attractive because they facilitate delivery of inputs and shipment of products. In the past, when most material moved in and out of a factory by rail, a central location was attractive because rail lines converged there. With trucks now responsible for transporting most inputs and products, proximity to major highways is more important for a factory. Especially attractive is the proximity to the junction of a long-distance route and the beltway, or ring road, that encircles most cities. Thus, factories cluster in industrial parks located near suburban highway junctions.



▲ **FIGURE 11-25 HISTORIC MULTISTORY FACTORY** In the early twentieth century, Ford assembled Model T cars in a multistory factory in Highland Park, Michigan. The bodies were slid down the ramp from the second floor and attached to the chassis, which rolled out of the first floor **1. When Ford built this factory in the early twentieth century, why were the exterior walls made almost entirely of glass? 2. What were the advantages and disadvantages of assembling large objects like cars in a multistory factory a century ago? 3. What technological advances during the past century have influenced replacement of multistory factories with one-story factories?**

▼ **FIGURE 11-26 MODERN ONE-STORY FACTORY** The Honda assembly plant in Swindon, United Kingdom, is spread out over one story.

Changing Site Factors: Clothing

LEARNING OUTCOME 11.2.6

Explain the distribution of clothing production.

Production of textiles (woven fabrics) and apparel (clothing) is a prominent example of an industry that generally requires less-skilled, low-cost workers. The textile and apparel industry accounts for 6 percent of the dollar value of world manufacturing but a much higher 14 percent of world manufacturing employment, an indicator that it is a labor-intensive industry. The percentage of the world's women employed in this type of manufacturing is even higher.

Textile and apparel production involves three principal steps:

- Spinning of fibers to make yarn.
- Weaving or knitting of yarn into fabric.
- Assembly of fabric into products.

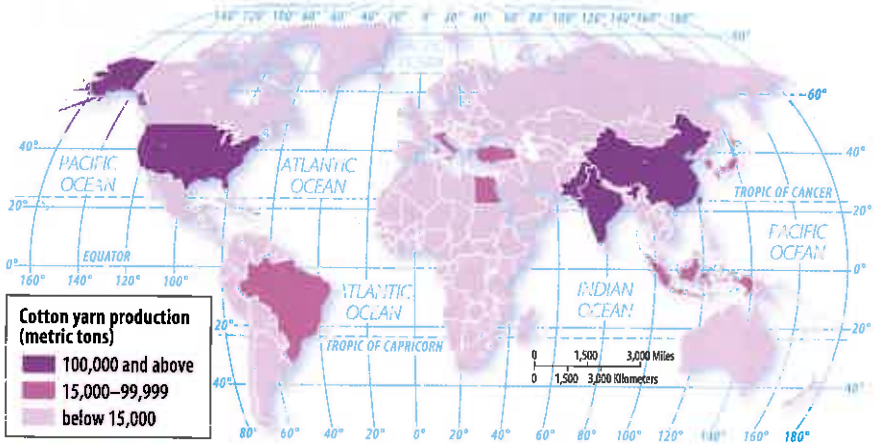
Spinning, weaving, and assembly are all labor intensive compared to other industries, but the importance of labor varies somewhat among them. Their global distributions are not identical because the three steps are not equally labor intensive.

SPINNING

Fibers can be spun from natural or synthetic elements. The principal natural fiber is cotton, and synthetics now account for three-fourths of world thread production. Because it is a labor-intensive industry, spinning is done primarily in low-wage countries (Figure 11-27). China produces one-fourth and India one-fifth of the world's cotton thread.

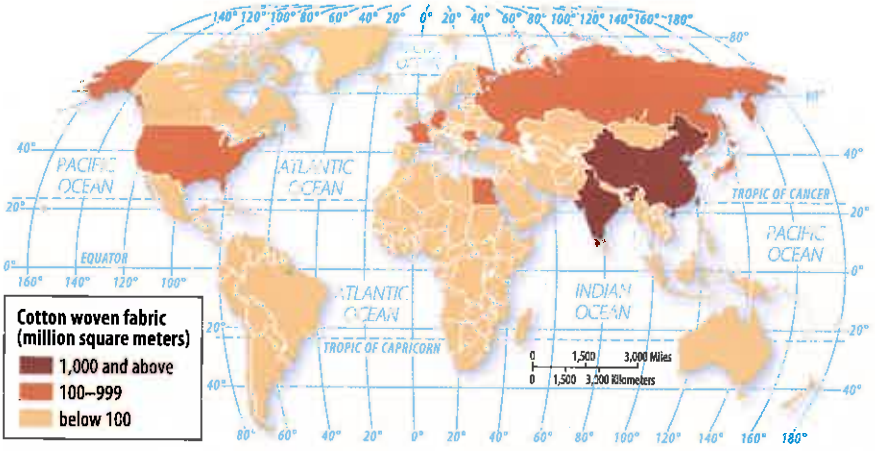
WEAVING

For thousands of years, fabric has been woven or laced together by hand on a loom, which is a frame on which two sets of threads are placed at right angles to each other. One set of threads, called the warp, is strung lengthwise. A second set of threads, called the weft, is carried in a shuttle that is inserted over and under the warp. Because the process of



(b)

▲ **FIGURE 11-27 COTTON SPINNING** **(a)** Nearly one-half of world cotton yarn is spun in China and India. **(b)** Factory in Indore, India, spins yarn from organic and fair trade cotton.



(b)

▲ **FIGURE 11-28 COTTON WEAVING** **(a)** China and India account for 90 percent of world cotton weaving. **(b)** Factory in India weaves textiles.

weaving by hand is physically hard work, weavers were traditionally men.

For mechanized weaving, labor constitutes a high percentage of the total production cost. Consequently, weaving is highly clustered in low-wage countries (Figure 11-28). Despite their remoteness from European and North American markets, China and India have become the dominant fabric producers because their lower labor costs offset the expense of shipping inputs and products long distances. China accounts for nearly 60 percent of the world's woven cotton fabric production and India 30 percent.

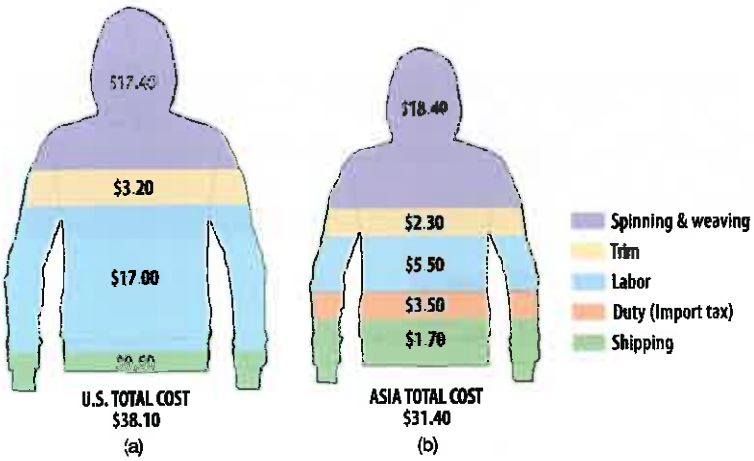
ASSEMBLY

Sewing by hand is a very old human activity. Needles made from animal horns or bones date back tens of thousands of years, and iron needles date from the fourteenth century. The first functional sewing machine was invented by French tailor Barthelemy Thimonnier in 1830. Isaac Singer manufactured the first commercially successful sewing machine in the United States during the 1850s.

Textiles are cut and sewn to be assembled into four main types of products: garments, carpets, home products such as bed linens and curtains, and industrial items such as headliners for motor vehicles. Developed countries play a larger role in assembly than in spinning and weaving because most of the consumers of assembled products are located in developed countries (Figure 11-29). Nonetheless, most clothing is assembled in developing countries. Overall production costs are generally lower in developing countries because substantially lower labor costs compared to developed countries offset higher shipping and taxation costs (Figure 11-30).

PAUSE & REFLECT 11.2.6

Check the label on the shirt you are wearing at this moment. Where was it made?

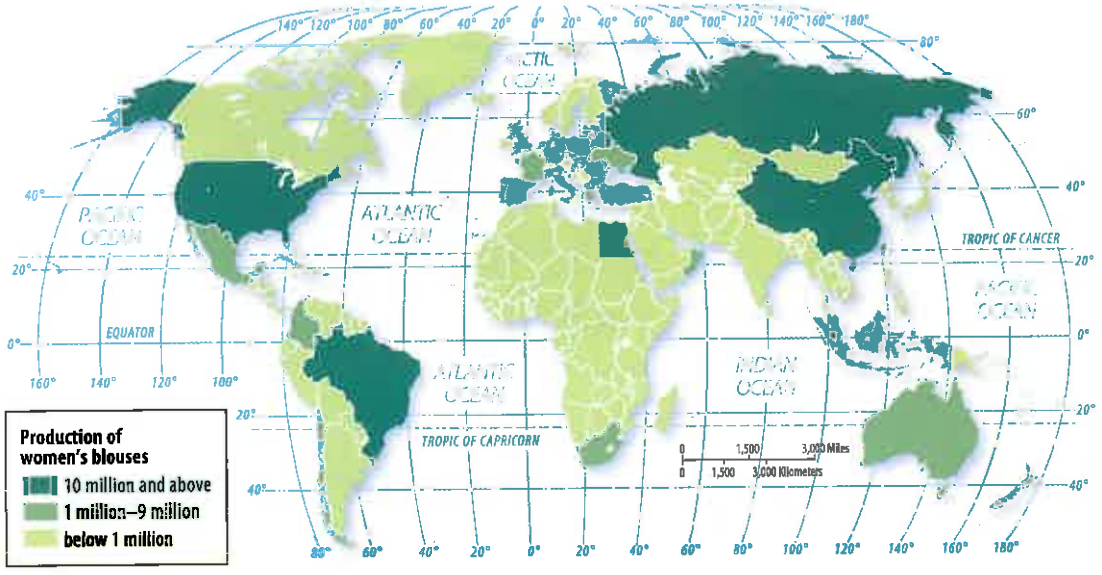


▲ **FIGURE 11-30 HOW MUCH IT COSTS TO MAKE A HOODIE SOLD IN THE UNITED STATES** The cost of production is lower **(b)** in Asia than **(a)** in the United States because of lower wages paid to clothing workers.

CHECK-IN KEY ISSUE 2

Why Are Situation and Site Factors Important?

- ✔ **Situation factors involve transporting materials to and from a factory.**
- ✔ **Bulk-reducing industries locate near their sources of inputs.**
- ✔ **Bulk-gaining, single-market, and perishable-products industries locate near their markets.**
- ✔ **Site factors derive from distinctive features of a particular place, including labor, capital, and land.**



▶ **FIGURE 11-29 WOMEN'S BLOUSE PRODUCTION** The United States is the leading producer of women's blouses.

KEY ISSUE 3

Why Do Industries Face Resource Challenges?

- Energy Supply
- Demand for Energy
- Fossil Fuel Reserves
- Petroleum Futures
- Nuclear Energy
- Energy Alternatives
- Solar Energy
- Air Pollution
- Water Pollution
- Solid Waste Pollution

LEARNING OUTCOME 11.3.1

Describe the distribution of production of the three fossil fuels.

Earth offers a large menu of resources available for people to use in factories, homes, and vehicles. A resource was defined in Chapter 1 as a substance in the environment that is useful to people, is economically and technologically feasible to access, and is socially acceptable to use. Geographers observe two challenges regarding resources:

- We deplete scarce resources, especially petroleum, natural gas, and coal, for energy production.
- We destroy resources through pollution of air, water, and soil.

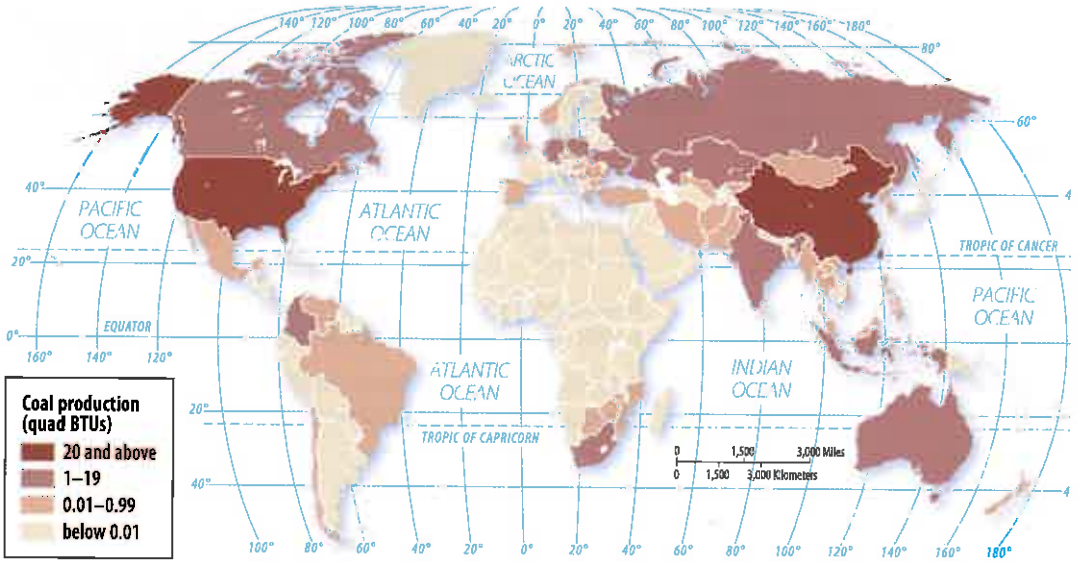


FIGURE 11-31 COAL PRODUCTION China is the world's leading producer of coal, followed by the United States.

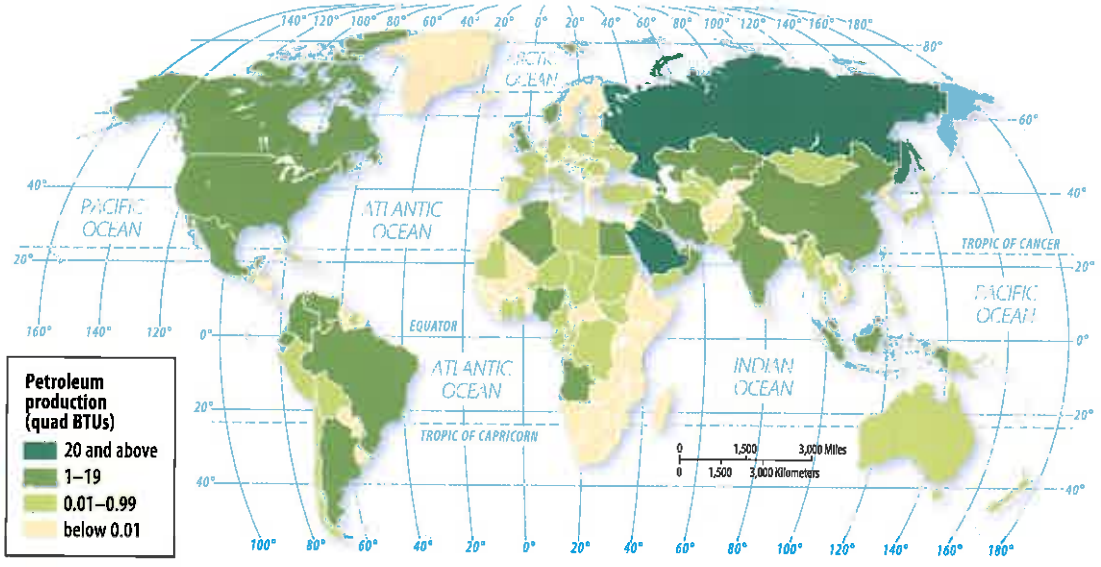
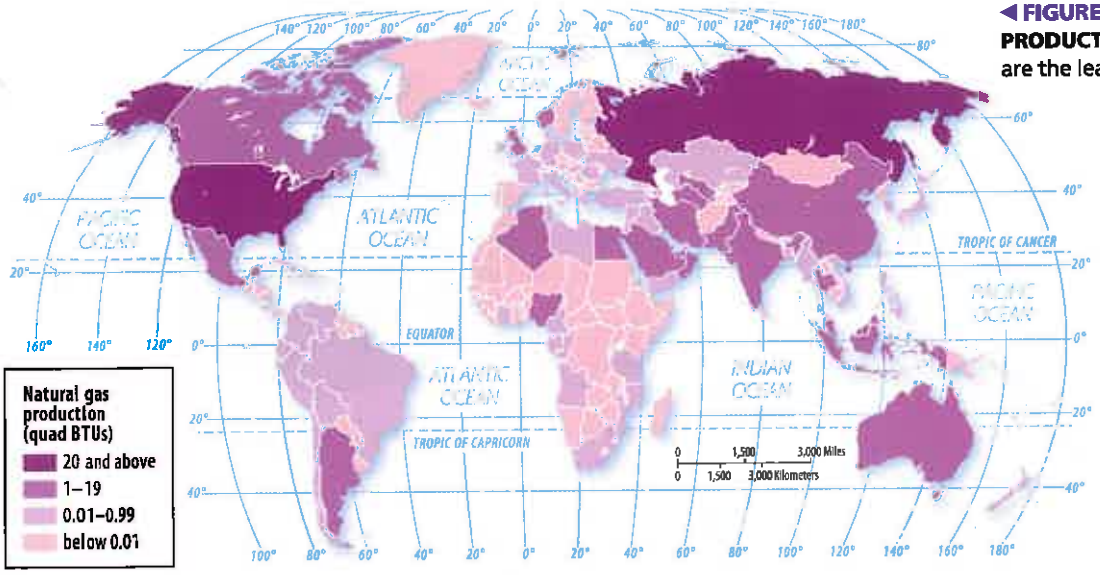


FIGURE 11-32 PETROLEUM PRODUCTION Russia, Saudi Arabia, and the United States are the leading producers of petroleum.



◀ **FIGURE 11-33 NATURAL GAS PRODUCTION** The United States and Russia are the leading producers of natural gas.

Energy Supply

Fossil fuels are not distributed evenly. Some regions are well endowed with one or more fossil fuels, whereas other regions have little. The uneven distribution of fossil fuels partly reflects how fossil fuels form:

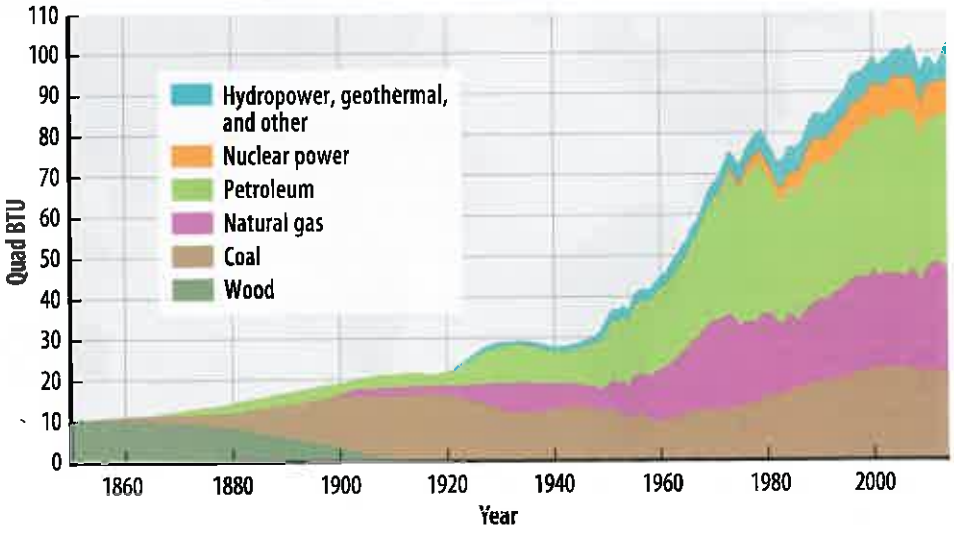
- **Coal.** Coal formed in tropical locations, in lush, swampy areas rich in plants. Thanks to the slow movement of Earth's drifting continents, the tropical swamps of 250 million years ago relocated to the mid-latitudes. As a result, today's main reserves of coal are in mid-latitude countries rather than in the tropics. China produces nearly one-half of the world's coal, other developing countries one-fourth, and developed countries (primarily the United States) the remaining one-fourth (Figure 11-31).
- **Petroleum.** Petroleum formed millions of years ago from residue deposited on the seafloor. Some still lies beneath such seas as the Persian Gulf and the North Sea, but other reserves are located beneath land that was under water millions of years ago. Russia and Saudi Arabia together supply one-fourth of the world's petroleum, other developing countries (primarily in Southwest and Central Asia) one-half, and developed countries (primarily the United States) the remaining one-fourth (Figure 11-32).
- **Natural gas.** Like petroleum, natural gas formed millions of years ago from sediment deposited on the seafloor. One-third of natural gas production is supplied by Russia and Southwest Asia, one-third by other developing regions, and one-third by developed countries (primarily the United States) (Figure 11-33).

Figures 11-31 11-32, and 11-33 use the same units (quad BTUs), as well as the same classes. Quad is short for quadrillion (1 quadrillion = 1,000,000,000,000,000), and BTU is short for British thermal unit. One quad BTU equals approximately 8 billion U.S. gallons of gasoline, which would fill the tanks of one-half million cars.

The United States is highly dependent on the three fossil fuels (Figure 11-34). Wood was the principal energy source in the nineteenth century. Coal became most important during the late nineteenth century, and petroleum and natural gas gained prominence during the second half of the twentieth century.

PAUSE & REFLECT 11.3.1

Which country produces at least 20 quad BTUs of all three fossil fuels?



▶ **FIGURE 11-34 CHANGING U.S. ENERGY SUPPLY** Petroleum, natural gas, and coal account for nearly 90 percent of all energy supplied in the United States.

Demand for Energy

LEARNING OUTCOME 11.3.2

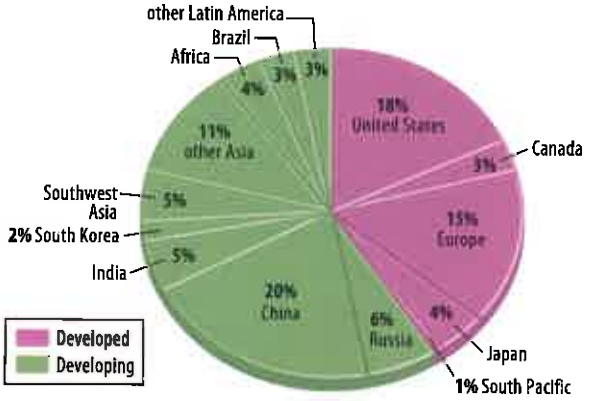
Explain the principal sources of demand for fossil fuels.

Industry depends on availability of abundant low-cost energy. Large quantities of energy are needed to run factories as well as to transport inputs into factories and products from factories to consumers. Energy is also needed to produce food, keep homes comfortable, and transport people.

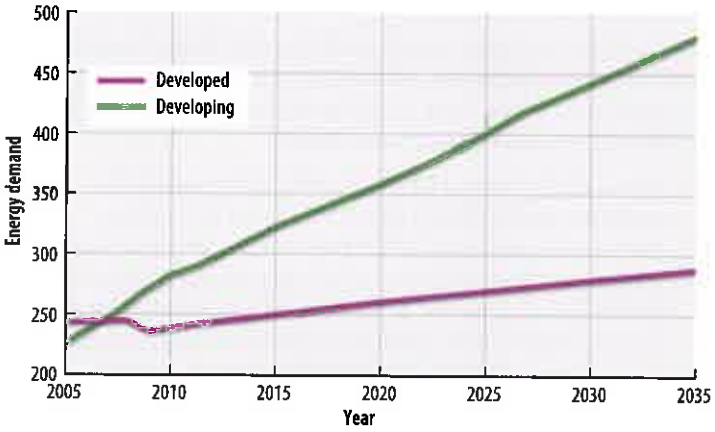
Demand for energy comes from four principal types of consumption in the United States:

- **Industries.** Factories use roughly 40 percent natural gas and 30 percent each coal and petroleum. Most of the natural gas and petroleum is burned directly, whereas coal is consumed primarily through purchasing electricity.
- **Transportation.** Almost all transportation systems run on petroleum products.
- **Homes.** Natural gas and coal provide roughly equal shares of home needs. Natural gas is the principal source of home heating and air conditioning, whereas electricity generated primarily from coal is the principal source of electricity.
- **Commercial.** Stores and offices have uses and sources similar to those for homes.

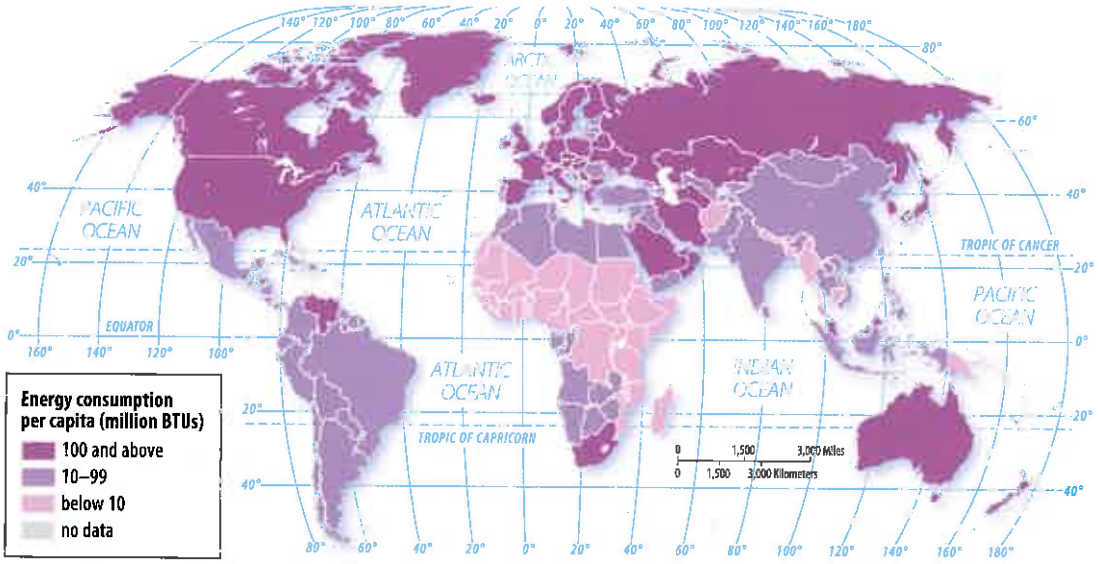
Developing countries accounted for more energy usage than developed countries for the first time in 2006 (Figure 11-35). The United States has long led in demand for energy, but China is now the leader. The highest per capita consumption of energy remains in developed countries (Figure 11-36). Consumption of fossil fuels has been increasing at a much faster rate in developing countries—around 3 percent per year, compared to 1 percent per year in developed countries. So the gap in demand between developing and developed countries will widen considerably in the years ahead (Figure 11-37).



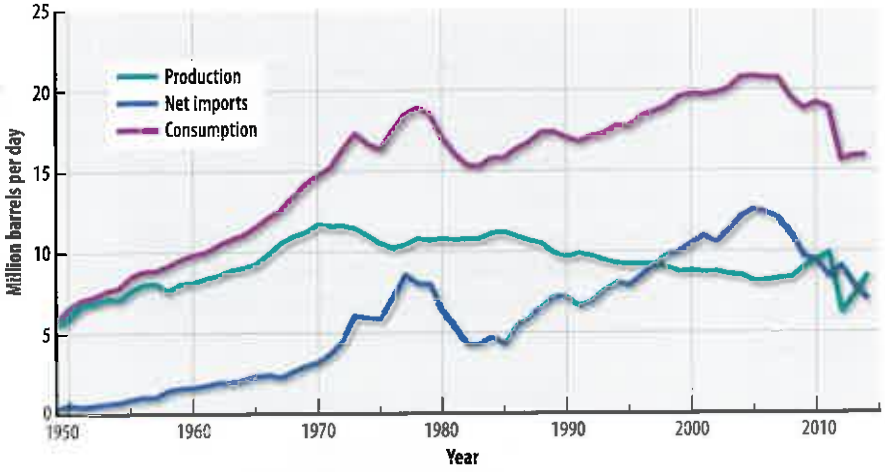
▲ **FIGURE 11-35 WORLD ENERGY DEMAND BY COUNTRY** Developing countries consume around 60 percent of the world's fossil fuels.



▲ **FIGURE 11-37 FUTURE ENERGY DEMAND** Developing countries will account for an increasing share of world energy usage in the years ahead.



▲ **FIGURE 11-36 ENERGY DEMAND PER CAPITA** The highest per capita consumption is in North America, and the lowest is in sub-Saharan Africa.



◀ **FIGURE 11-38 U.S. PETROLEUM SUPPLY AND DEMAND** The United States imports more than it produces in order to meet demand for consumption.

PETROLEUM CHALLENGES

Meeting world demand for petroleum has been especially challenging in recent years. Most of the world's petroleum is produced in Southwest Asia & North Africa and Central Asia, the two regions at the center of religious, ethnic, and political conflicts discussed in Chapters 6 through 8.

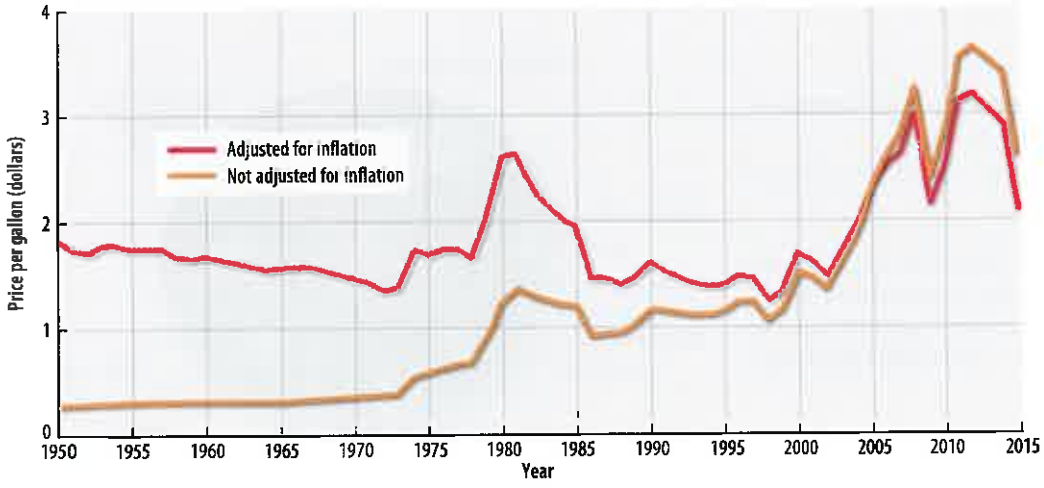
Other developed countries have always depended on foreign petroleum because of limited domestic supplies, but the United States produced more petroleum than it consumed during the first half of the twentieth century. Beginning in the 1950s, the handful of large transnational companies then in control of international petroleum distribution determined that extracting petroleum in the United States was more expensive than importing it from Southwest and Central Asia. U.S. petroleum imports increased from 14 percent of total consumption in 1955 to 60 percent in 2005, before declining to 44 percent in 2014 (Figure 11-38).

Several developing countries possessing substantial petroleum reserves, primarily in Southwest Asia & North Africa, created the Organization of the Petroleum Exporting Countries (OPEC) in 1960. OPEC was originally formed to enable oil-rich countries to gain more control over their resource. U.S. and European transnational companies, which had originally explored and exploited the oil fields, were selling the petroleum at low prices to consumers in developed countries and keeping most of the profits. Countries possessing the oil reserves nationalized or more tightly controlled the fields, and prices were set by governments rather than by petroleum companies.

Under OPEC control, world oil prices have increased sharply on several occasions, especially during the 1970s and 1980s and in the early twenty-first century. Developed countries entered the twenty-first century optimistic that oil prices would remain low for some time. But in 2008, prices hit a record high, in both real terms and accounting for inflation. The 2008 oil shock contributed to the severe global recession that began that year. Gas prices are currently low in the United States, especially when adjusted for inflation (Figure 11-39). However, the average price paid for a gallon of petroleum exceeds $8 in most other developed countries.

PAUSE & REFLECT 11.3.2

Referring to Figure 11-36, what world region of developing countries appears to have the highest per capita demand for energy?



◀ **FIGURE 11-39 U.S. GASOLINE PRICES** Fuel prices increased sharply in the 1970s and again in the 2000s but declined a few years after both periods.

Fossil Fuel Reserves

LEARNING OUTCOME 11.3.3

Understand the distinctive distributions of reserves of the three fossil fuels.

Because petroleum, natural gas, and coal are deposited beneath Earth's surface, considerable technology and skill are required to locate these substances and estimate their volume. The supply of energy remaining in deposits that have been discovered is called a **proven reserve.**

PROVEN RESERVES

Developed countries have historically possessed a disproportionately high supply of the world's proven fossil fuel reserves (Figure 11-40):

- **Coal.** World reserves are approximately 1 trillion metric tons (23,000 quad BTUs). At current demand, proven coal reserves would last 130 years. Developed and developing regions each have about one-half of the supply of proven reserves. The United States has approximately one-fourth of the proven reserves, and other developed countries have one-fourth. Most of the developing regions' coal reserves are in Russia and China.
- **Natural gas.** World reserves are approximately 200 trillion cubic meters (7,000 quad BTUs). At current demand, proven natural gas reserves would last 56 years. Less than 10 percent of natural gas reserves are in developed countries, primarily the United States. Russia has 25 percent and Iran and Qatar together 30 percent of the world's proven natural gas reserves.
- **Petroleum.** World reserves are approximately 1.6 trillion barrels (10,000 quad BTUs). At current demand, proven petroleum reserves would last 55 years. Developing countries possess 87 percent of the proven petroleum reserves, most of which is in Southwest Asia & North Africa and Central Asia. Venezuela, Saudi Arabia, Canada, Iran, and Iraq together have nearly two-thirds of the world's proven petroleum reserves.

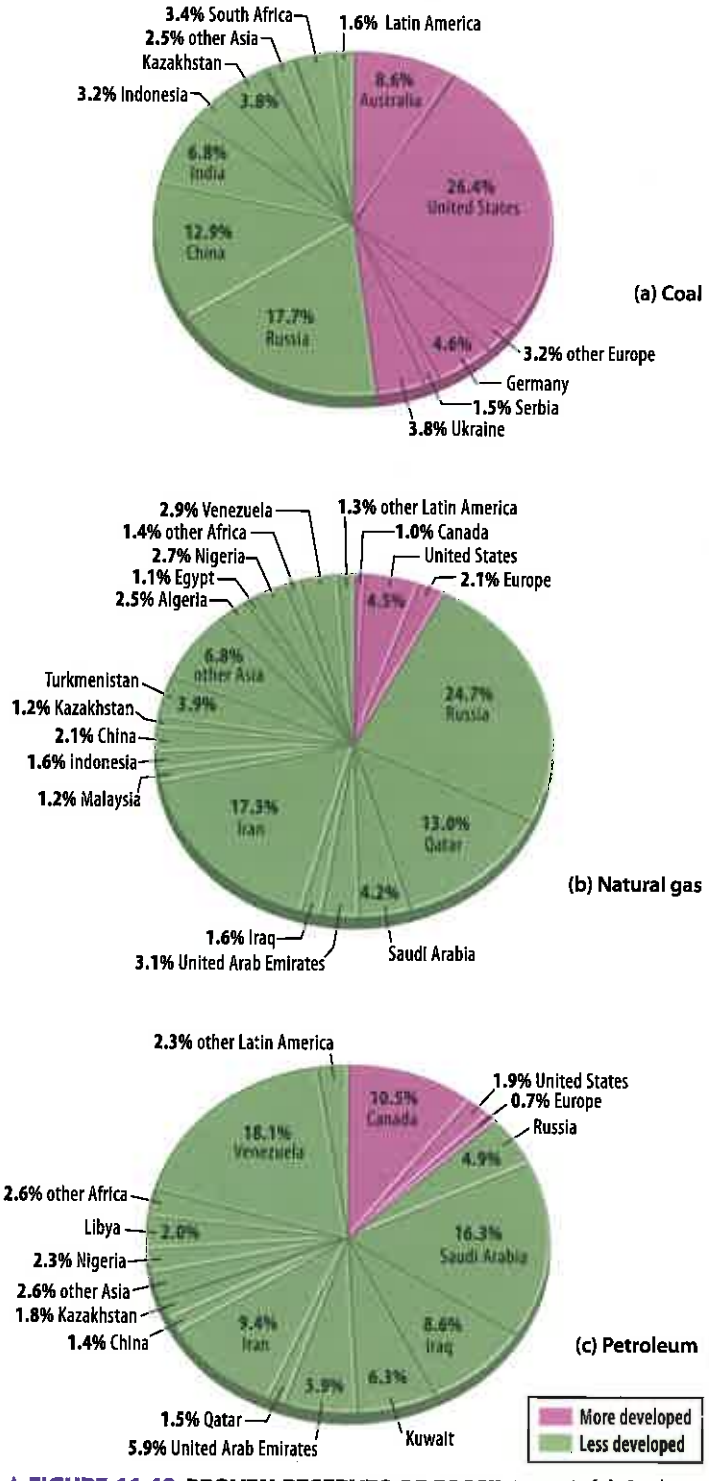
PAUSE & REFLECT 11.3.3

What are the only two countries named on all three pie charts of proven reserves?

POTENTIAL RESERVES

The supply in deposits that are undiscovered but thought to exist is a **potential reserve.** When a potential reserve is actually discovered, it is reclassified as a proven reserve (Figure 11-41). Potential reserves can be converted to proven reserves in several ways:

- **Fields yet to be developed.** When it was first exploited, petroleum "gushed" from wells drilled into rock layers saturated with it. Coal was quarried in open pits. But now extraction is more difficult. Removing the last supplies from a proven field is comparable to wringing out a soaked towel. It is easy to quickly remove the main volume of water, but the last few drops require more effort—in the case of petroleum, more time, more expense, and special technology.
- **Fields yet to be discovered.** The largest, most accessible deposits of petroleum, natural gas, and coal have already been exploited. Newly discovered reserves are generally smaller and more remote, such



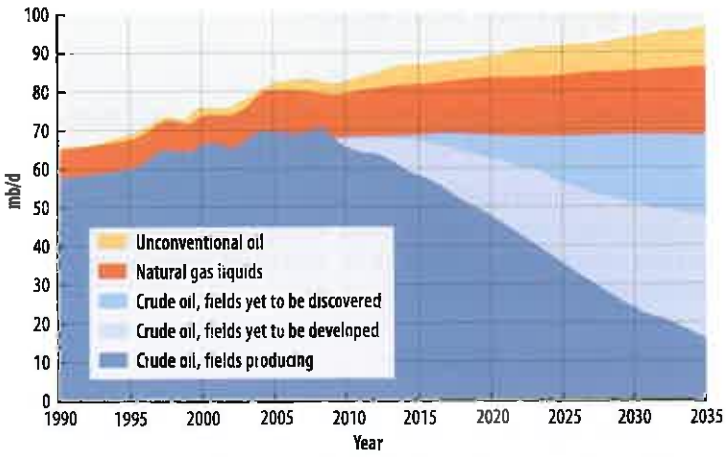
▲ **FIGURE 11-40 PROVEN RESERVES OF FOSSIL FUELS** **(a)** Coal. **(b)** Natural gas. **(c)** Petroleum.

as beneath the seafloor, and extraction is costly. Exploration costs have increased because methods are more elaborate, and the probability of finding new reserves is lower. But as energy prices climb, exploration costs may be justified.

UNCONVENTIONAL RESOURCES

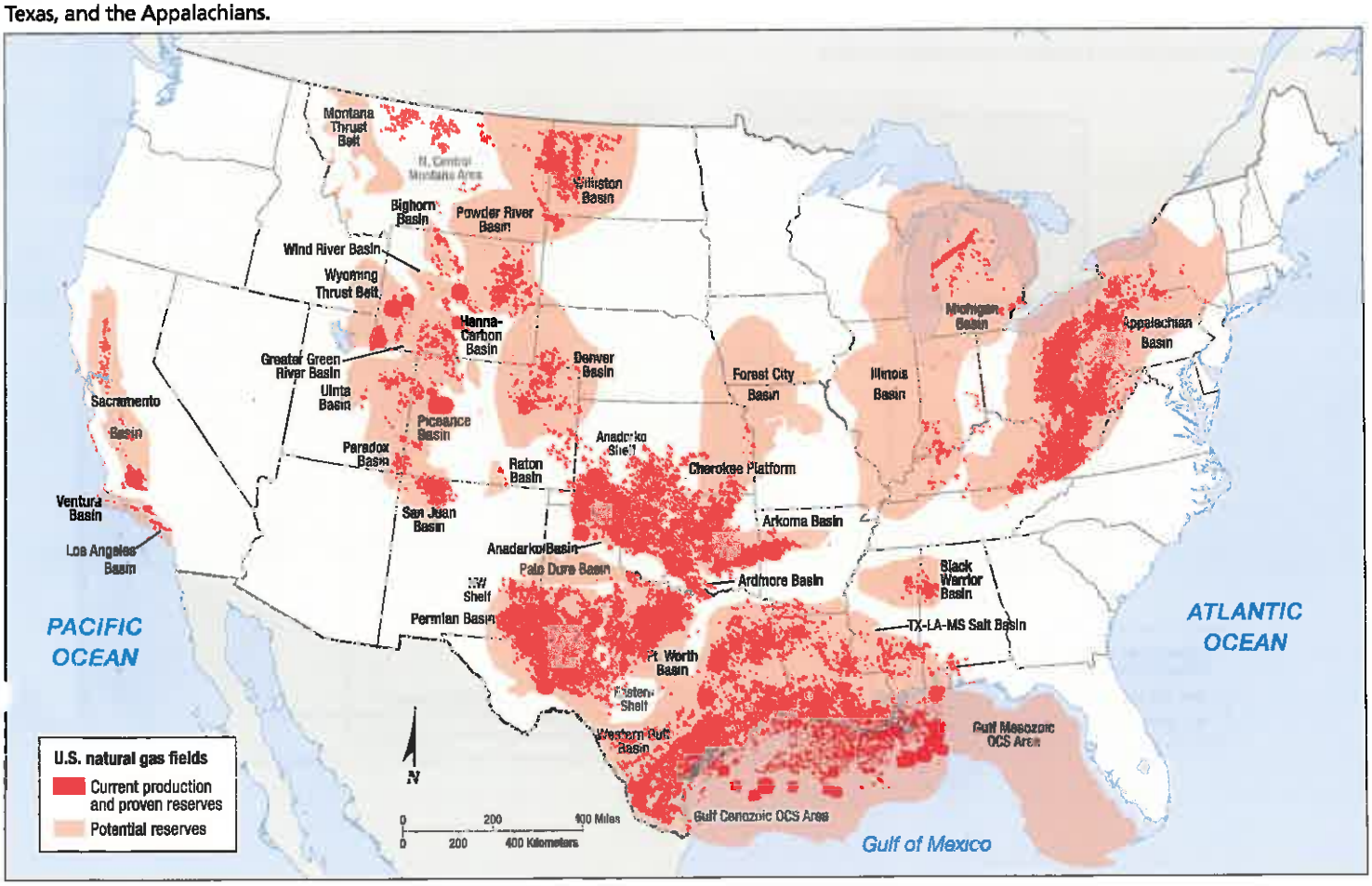
Resources are considered unconventional if we lack economically feasible or environmentally sound technology with which to extract them. As demand increases for a resource and prices rise, exploiting an unconventional source can become profitable. Here are two current examples:

- **Oil sands.** Abundant oil sands are found in Alberta, Canada, as well as in Venezuela and Russia. Oil sands are saturated with thick petroleum commonly called tar because of its dark color and strong odor. The mining of Alberta oil sands has become profitable, and extensive deposits of oil in Alberta oil sands have been reclassified from potential to proven reserves in recent years. As a result, Canada is now thought to have 11 percent of world's petroleum proven reserves, second behind Saudi Arabia.
- **Hydraulic fracturing.** Rocks break apart naturally, and gas can fill the space between the rocks. Hydraulic fracturing, commonly called *fracking*, involves pumping water at high pressure to further break apart rocks and thereby release more gas that can be extracted. The United States has extensive natural gas fields, some of which are now being exploited through fracking. Opponents of fracking fear environmental damage from pumping high-pressure water beneath Earth's surface. Safety precautions can minimize the environmental threat, but fracking does require the use of a large supply of water, and water is in high demand for other important uses, such as human consumption and agriculture. Within the United States, the principal natural gas fields are in Texas, Oklahoma, and the Appalachian Mountains (Figure 11-42).



▲ **FIGURE 11-41 PETROLEUM PRODUCTION OUTLOOK** The International Energy Agency forecasts that potential reserves will be converted to proven reserves through discovery and development of new fields at about the same rate as already proven reserves are depleted.

▼ **FIGURE 11-42 NATURAL GAS FIELDS IN THE UNITED STATES** The principal natural gas fields are in Oklahoma, Texas, and the Appalachians.



Petroleum Futures

LEARNING OUTCOME 11.3.4

Understand changing patterns of oil trade and demand.

Developed countries supply a large share of the world's fossil fuels, but they demand more energy than they produce, so they must import fossil fuels, especially petroleum, from developing countries (Figure 11-43).

▲ **FIGURE 11-43 OIL REFINERY, SAUDI ARABIA**

WORLD OIL TRADE

The largest flows of oil are from Russia to Europe and from Southwest Asia to Europe and to Japan (Figure 11-44). The United States and Europe import more than half their petroleum, and Japan imports more than 90 percent.

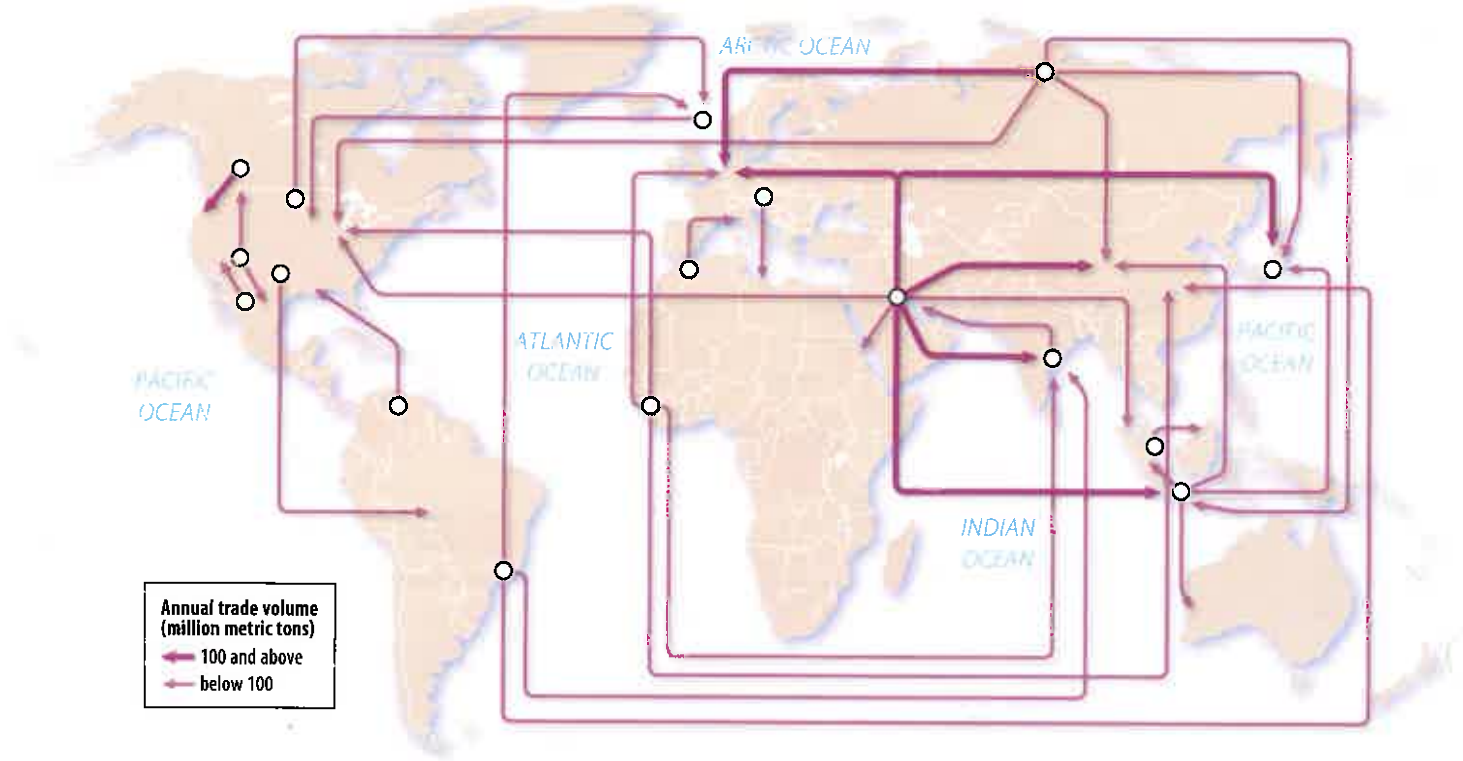
The countries from which the United States imports petroleum have changed since 1973. Canada and Saudi Arabia now supply much higher shares than in the past (Figure 11-45). With demand increasing rapidly in developing countries, developed countries face greater competition in obtaining the world's remaining supplies of fossil fuels. Many of the developing countries with low HDIs also lack energy resources, and they lack the funds to pay for importing them.

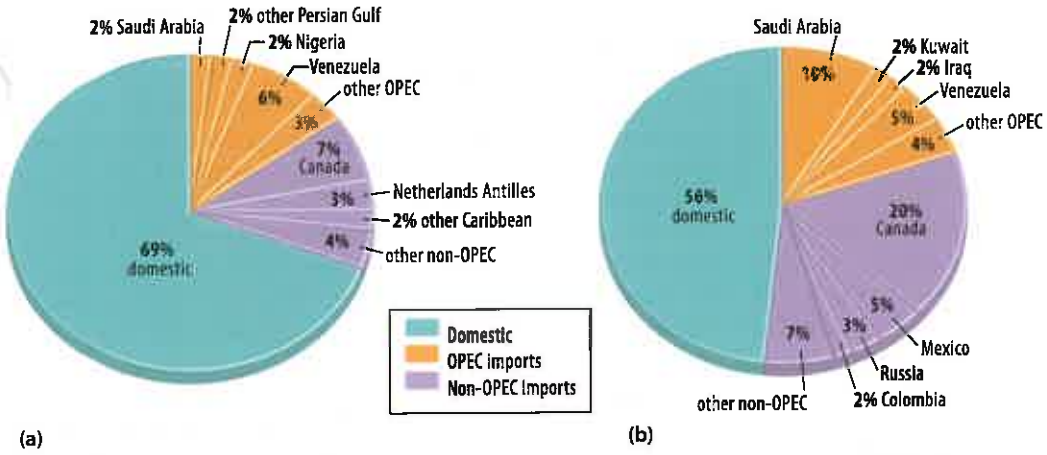
DECLINING DEMAND

Demand for petroleum has been dampened in developed countries through conservation. Factories have reduced their demand for petroleum, primarily by consuming more natural gas. The average vehicle driven in the United States got 14 miles per gallon in 1975 and 22 miles per gallon in 1985, and it will get an anticipated 54 miles per gallon in 2025. A government mandate known as Corporate Average Fuel Economy (CAFE) has been responsible for the higher standard.

Other countries also mandate more fuel-efficient vehicles (see Chapter 13). The U.S. Department of Energy forecasts that energy consumption in the United States will

▼ **FIGURE 11-44 PETROLEUM TRADE** The largest flows of petroleum are from Latin America to the United States and from Southwest Asia to Europe and elsewhere in Asia.





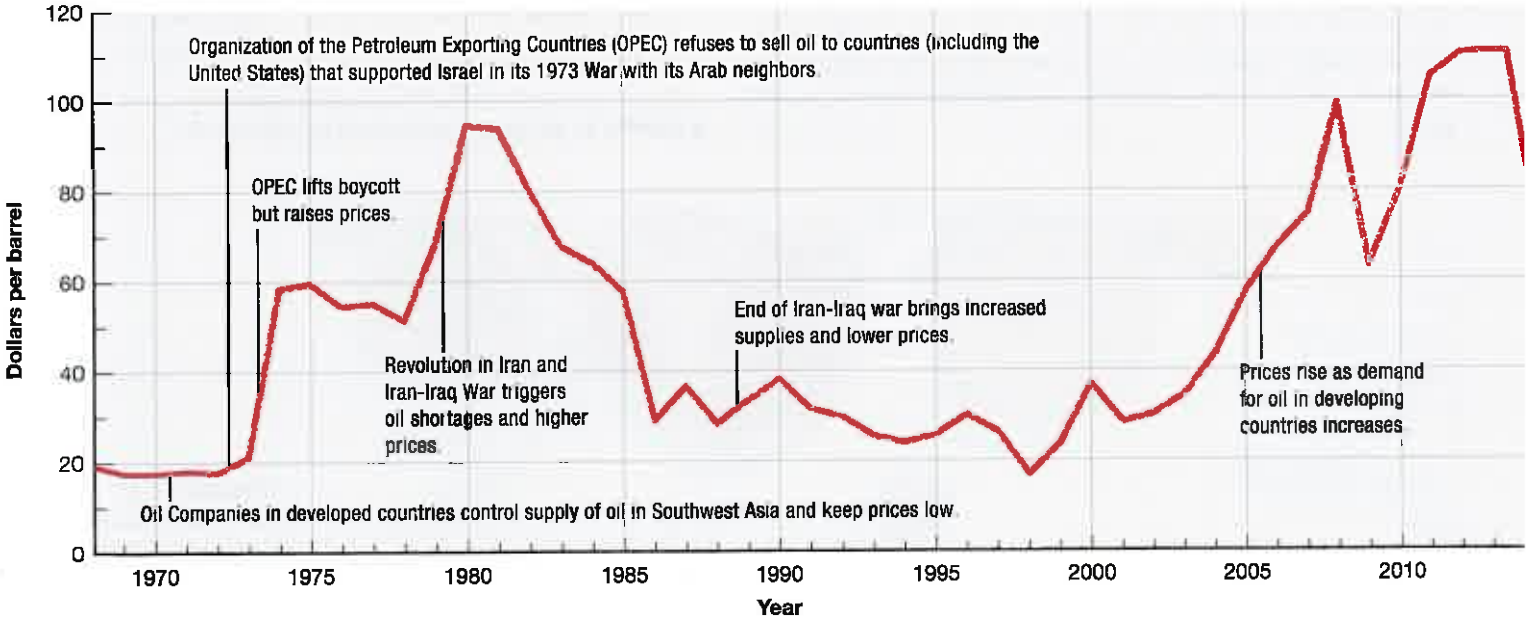
▲ **FIGURE 11-45 U.S. PETROLEUM SOURCES** The United States imports a higher percentage of petroleum **(a)** now than **(b)** in the 1970s. The largest increases have come from Canada and Saudi Arabia.

increase from 97.1 quad BTU in 2013 to 105.7 quad BTU in 2040. Because of population increase, consumption per person is forecast to decline by 10 percent. Consumption of natural gas and energy from sources other than fossil fuels are expected to increase, whereas consumption of petroleum and coal are expected to remain virtually unchanged. However, demand for petroleum can fall if the price rises or increase if the price declines (Figure 11-46).

The world will not literally "run out" of petroleum during the twenty-first century. However, at some point, extracting the remaining petroleum reserves will be so expensive and environmentally damaging that use of alternative energy sources will accelerate, and dependency on petroleum will diminish. The issues for the world are whether dwindling petroleum reserves are handled wisely and other energy sources are substituted peacefully. Given the massive growth in petroleum consumption expected in developing countries such as China and India, the United States and other developed countries may have little influence over when prices rise and when supplies decline. In this challenging environment, all countries will need to pursue sustainable development strategies based on increased reliance on renewable energy sources.

PAUSE & REFLECT 11.3.4

Do you consider fuel efficiency when you or your family buy a new vehicle? Why or why not?



▲ **FIGURE 11-46 OIL PRICE HISTORY** Oil prices have changed sharply on several occasions.

Nuclear Energy

LEARNING OUTCOME 11.3.5

Describe the distribution of nuclear energy and challenges in using it.

Nuclear power is not renewable, but some view it as an alternative to fossil fuels. The big advantage of nuclear power is the large amount of energy released from a small amount of material. One kilogram of enriched nuclear fuel contains more than 2 million times the energy in 1 kilogram of coal. However, nuclear power presents serious challenges.

DISTRIBUTION OF NUCLEAR POWER

Nuclear power supplies 14 percent of the world's electricity. Two-thirds of the world's nuclear power is generated in developed countries, with Europe and North America responsible for generating one-third each. Only 30 of the world's nearly 200 countries make some use of nuclear power, including 19 developed countries and only 11 developing countries. The countries most highly dependent on nuclear power are clustered in Europe (Figure 11-47), where it supplies 80 percent of all electricity in France and more than 50 percent in Belgium, Slovakia, and Ukraine.

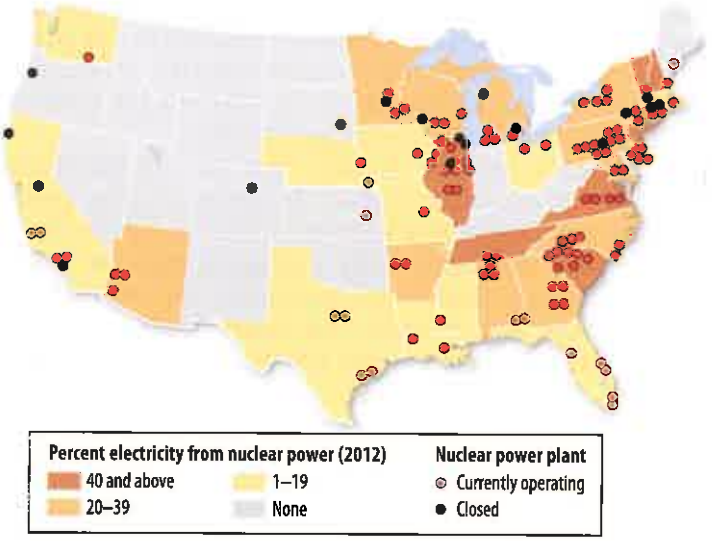
Dependency on nuclear power varies widely among U.S. states (Figure 11-48). Nuclear power accounts for more than 70 percent of electricity in Vermont and more than one-half in Connecticut, New Jersey, and South Carolina. At the other extreme, 20 states and the District of Columbia have no nuclear power plants.

POTENTIAL ACCIDENTS

A nuclear power plant produces electricity from energy released by splitting uranium atoms in a controlled environment, a process called **fission**. One product of all nuclear reactions is radioactive waste, certain types of which are lethal to people exposed to it. Elaborate safety precautions are taken to prevent the leaking of nuclear fuel from a power plant.

Nuclear power plants cannot explode, like a nuclear bomb, because the quantities of uranium are too small and cannot be brought together fast enough. However, it is possible to have a runaway reaction, which overheats the reactor, causing a meltdown, possible steam explosions, and scattering of radioactive material into the atmosphere. This happened in 1986 at Chernobyl, then in the Soviet Union and now in the north of Ukraine, near the Belarus border. The accident caused 56 deaths due to exposure to high radiation doses and an estimated 4,000 cancer-related deaths to people who lived near the plant.

Following an earthquake and tsunami in 2011, three of the six reactors at Japan's Fukushima Daiichi nuclear power plant experienced full meltdown, resulting in release of radioactive materials. Three workers died; the death toll among nearby residents exposed to high levels of radioactivity won't be known for years.



▲ **FIGURE 11-48 NUCLEAR POWER BY U.S. STATE**

◀ **FIGURE 11-47 ELECTRICITY FROM NUCLEAR POWER** The size of the country reflects the proportion of the world's nuclear power generated there.

RADIOACTIVE WASTE

The waste from nuclear fission is highly radioactive and lethal, and it remains so for many years. Plutonium for making nuclear weapons can be harvested from this waste. Pipes, concrete, and water near the fissioning fuel also become "hot" with radioactivity. No one has yet devised permanent storage for radioactive waste. The waste cannot be burned or chemically treated, and it must be isolated for several thousand years until it loses its radioactivity. Spent fuel in the United States is stored "temporarily" in cooling tanks at nuclear power plants, but these tanks are nearly full.

The United States is Earth's third-largest country in land area, yet it has failed to find a suitable underground storage site because of worry about groundwater contamination. In 2002, the U.S. Department of Energy approved a plan to store the waste in Nevada's Yucca Mountains. But soon after taking office in 2009, the Obama administration reversed the decision and halted construction on the nearly complete repository.

BOMB MATERIAL

Nuclear power has been used in warfare twice, in August 1945, when the United States dropped atomic bombs on Hiroshima and Nagasaki, Japan, ending World War II. No government has dared to use these bombs in a war since then because leaders recognize that a full-scale nuclear conflict could terminate human civilization.

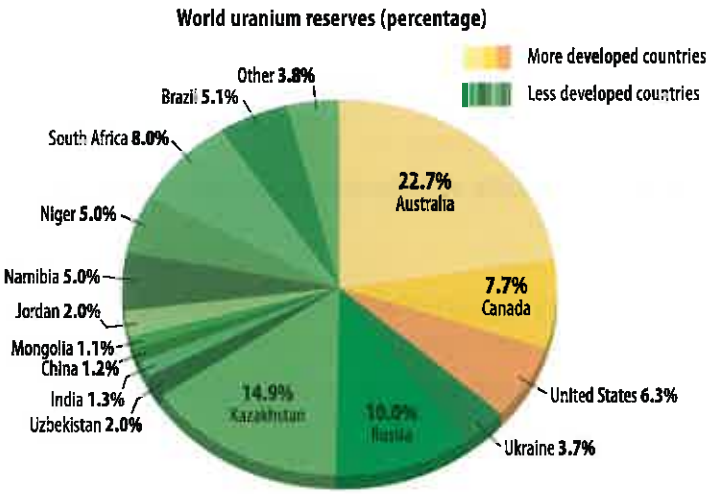
The United States and Russia (previously the Soviet Union) each have several thousand nuclear weapons. China, France, and the United Kingdom have several hundred nuclear weapons each, India and Pakistan several dozen each, and North Korea a handful. Israel is suspected of possessing nuclear weapons but has not admitted to it, and Iran has been developing the capability. Other countries have initiated nuclear programs over the years but have not advanced to the weapons stage. The diffusion of nuclear programs to countries sympathetic to terrorists has been particularly worrying to the rest of the world and has been a major factor in long-time tensions between Iran and other countries that do not want Iran to gain the capability of building a nuclear weapon.

PAUSE & REFLECT 11.3.5

Should dependency on nuclear energy be increased or decreased? Why?

LIMITED RESERVES

Like fossil fuels, uranium is a nonrenewable resource. Proven uranium reserves will last about 124 years at current rates of use. And they are not distributed uniformly around the world: Australia has 23 percent of the world's proven uranium reserves, Kazakhstan 15 percent, and Russia 10 percent (Figure 11-49).



▲ **FIGURE 11-49 WORLD URANIUM RESERVES**

The chemical composition of natural uranium further aggravates the scarcity problem. Uranium ore naturally contains only 0.7 percent U-235; a greater concentration is needed for power generation.

A breeder reactor turns uranium into a renewable resource by generating plutonium, also a nuclear fuel. However, plutonium is more lethal than uranium and could cause more deaths and injuries in an accident. It is also easier to fashion into a bomb. Because of these risks, few breeder reactors have been built, and none are in the United States.

HIGH COST

Nuclear power plants cost several billion dollars to build, primarily because of the elaborate safety measures required. Without double and triple backup systems at nuclear power plants, nuclear energy would be too dangerous to use. Uranium is mined in one place, refined in another, and used in still another. As with coal, mining uranium can pollute land and water and damage miners' health. The complexities of safe transportation add to the cost. As a result, generating electricity from nuclear plants is much more expensive than from coal-burning plants. The future of nuclear power has been seriously hurt by the high costs associated with reducing risks.

Some nuclear power issues might be addressed through nuclear **fusion**, which is the fusing of hydrogen atoms to form helium. Fusion can occur only at very high temperatures (millions of degrees) that cannot been generated on a sustained basis in a power-plant reactor with current technology.

Energy Alternatives

LEARNING OUTCOME 11.3.6

Identify alternative sources of energy and challenges to using them.

Earth's energy resources are divided between those that are renewable and those that are not:

- **Nonrenewable energy** resources form so slowly that for practical purposes, they cannot be renewed. Examples are the three fossil fuels that currently supply most of the world's energy needs.
- **Renewable energy** resources have an essentially unlimited supply and are not depleted when used by people. Water, wind, and the Sun provide sources of renewable energy.

HYDROELECTRIC POWER

Generating electricity from the movement of water is called hydroelectric power (Figure 11-50). Hydroelectric is now the world's second-most-popular source of electricity, after coal. Two-thirds of the world's hydroelectric power is generated in developing countries and one-third in developed countries. A number of developing countries depend on hydroelectric power for most of their electricity (Figure 11-51).

The most populous country to depend primarily on hydroelectric power is Brazil. Brazil has made considerable progress toward sustainable development by generating 80 percent of its electricity from hydroelectric power and 7 percent from other renewable sources.

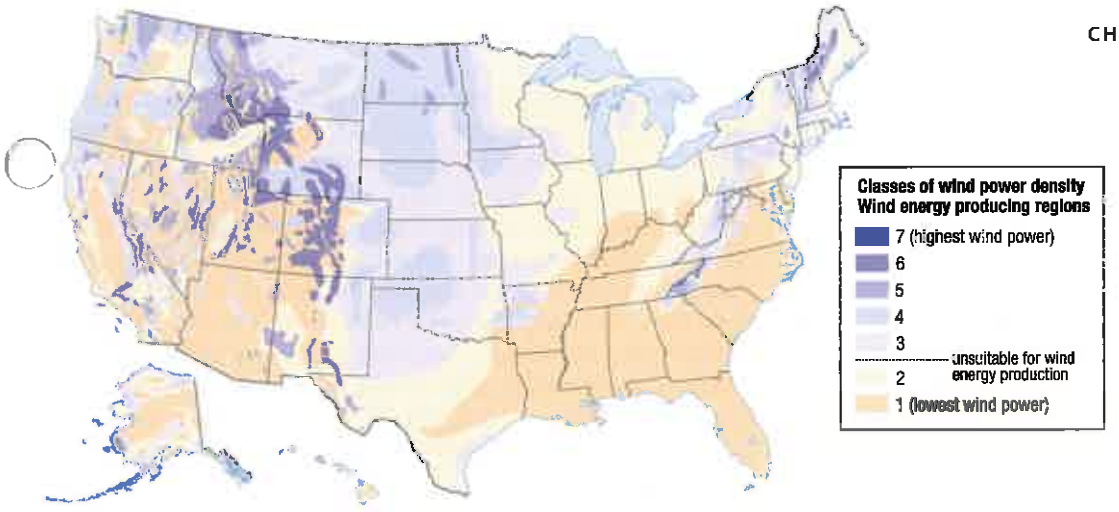
▲ **FIGURE 11-50 HYDROELECTRIC POWER** Cheoah Dam in Tapoco, Tennessee, provides electricity for Alcoa's nearby aluminum factory.

Among developed countries, Canada gets 60 percent of its electricity from hydroelectric power. The United States is a leading producer of hydroelectric power, but obtains only 8 percent of its electricity from that source. This percentage may decline because few acceptable sites to build new dams remain.

BIOMASS

Biomass fuel is fuel derived from plant material and animal waste. Biomass energy sources include wood and crops. When carefully harvested in forests, wood is a renewable resource that can be used to generate electricity and heat. The waste from processing wood, such as for building construction and demolition, is also available. And crops such as sugarcane, corn, and soybeans can be processed into motor-vehicle fuels. Worldwide production of biomass fuel is approximately 3 quad BTUs, including one-third each

▲ **FIGURE 11-51 ELECTRICITY FROM HYDROELECTRIC POWER**



◀ **FIGURE 11-52 WIND POWER** Winds are especially strong enough to support generation of power in the U.S. Plains states.

in North America, Europe, and developing regions. Brazil makes extensive use of biomass to fuel its cars and trucks.

The potential for increasing the use of biomass for fuel is limited, for several reasons:

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

WIND POWER

The benefits of wind-generated power seem irresistible. Construction of a wind turbine modifies the environment less severely than does construction of a dam. And wind power has greater potential for increased use because only a small portion of the resource has been harnessed.

Despite its attractions, wind power has been harnessed in only a few places. China, North America, and Europe together account for 90 percent of total world production. A significant obstacle for developing countries is the high cost of constructing wind turbines.

Hundreds of wind "farms" consisting of large numbers of wind turbines have been constructed across the United States. One-third of the country is considered windy enough to make wind power economically feasible (Figure 11-52).

Wind power has divided the environmental community. Some oppose construction of wind turbines because they can be noisy and lethal for birds and bats. Some also find them a visual blight when they're constructed in places of outstanding beauty (Figure 11-53).

▼ **FIGURE 11-53 WIND TURBINE FARM** Makara Wind Farm, near Wellington, New Zealand.

GEOTHERMAL ENERGY

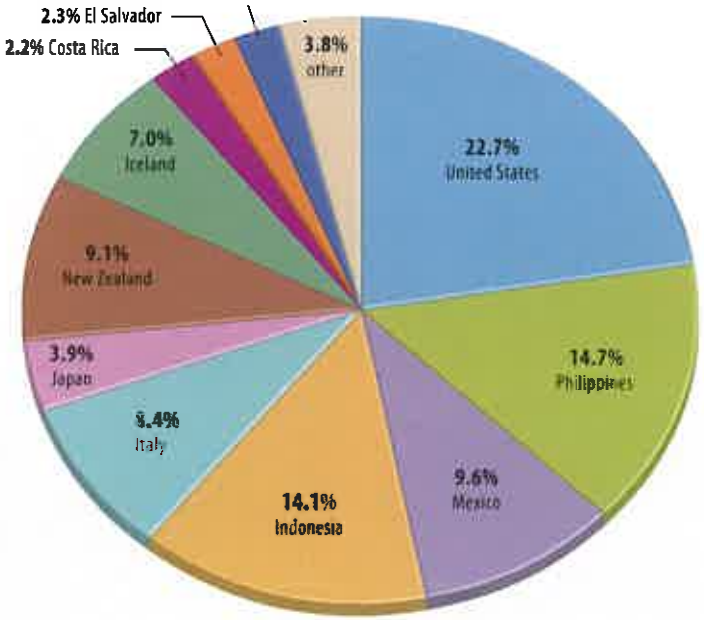
Energy from this hot water or steam is called **geothermal energy.** Natural nuclear reactions make Earth's interior hot. Toward the surface, in volcanic areas, this heat is especially pronounced. The hot rocks can encounter groundwater and produce heated water or steam that can be tapped by wells.

Harnessing geothermal energy is most feasible at sites along Earth's surface where crustal plates meet, which are also the sites of many earthquakes and volcanoes. The United States, the Philippines, and Indonesia are the leading producers of geothermal power (Figure 11-54). Ironically, in Iceland, named for its glaciers, nearly all homes and businesses in the capital Reykjavik are heated with geothermal steam.

PAUSE & REFLECT 11.3.6

Does your local power company offer options for using alternative energy? Check the company's website.

▼ **FIGURE 11-54 DISTRIBUTION OF GEOTHERMAL ENERGY**



Solar Energy

LEARNING OUTCOME 11.3.7

Compare passive and active solar energy.

The ultimate renewable resource for sustainable development is solar energy supplied by the Sun. Solar energy offers the possibility for countries at low levels of development to promote sustainable development. Through solar energy, people and businesses in developing countries currently unable to obtain electricity can generate energy needed to operate businesses, schools, and hospitals.

Solar sources currently supply the United States with only 1 percent of electricity, but the potential for growth is limitless. The Sun's remaining life is estimated at 5 billion years, and humans appear to be incapable of destroying or depleting that resource. The Sun's energy is free and ubiquitous and cannot be exclusively owned, bought, or sold by any particular individual or enterprise. Utilizing the Sun as a resource does not damage the environment or cause pollution, as does the extraction and burning of nonrenewable fossil fuels.

PASSIVE SOLAR ENERGY

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

Reliance on passive solar energy increased during the nineteenth century when construction innovations first permitted the hanging of massive glass "curtains" on a thin steel frame. Greenhouses enabled people to grow and view vegetation that required more warmth to flourish than the local climate permitted. Early skyscrapers made effective use of passive solar energy. During World War II when fossil fuels were rationed, consumers looked for alternative energy sources. A major glass manufacturer, Libbey-Owens-Ford Glass Co., responded by publishing a book in 1947 entitled Your Solar House. But with electricity and petroleum cheap and abundant after World War II and through most of the twentieth century, passive solar energy rarely played a major role in construction of homes and commercial buildings.

In recent years, building construction and remodeling have made more use of passive solar energy through advances in glass technology. Double- and triple-pane windows have higher insulating values, and low-E (low emissivity) glass can be coated to let heat in but not out. Window panes made with this glass are filled with argon or other gases that increase their insulating values beyond that of windows that have just air between the panes. Phase-change technologies can also switch the glass from opaque to translucent when a voltage is applied.

PAUSE & REFLECT 11.3.7

Why are people warned not to leave a dog or child unattended in a parked car during the summer?

ACTIVE SOLAR ENERGY

Active solar energy systems collect solar energy and convert it either to heat energy or to electricity (Figure 11-55). The conversion can be accomplished either directly or indirectly.

In direct electric conversion, solar radiation is captured with photovoltaic cells, which convert light energy

◀ FIGURE 11-55
SOLAR ENERGY
Solar panels generate electricity in Odoru, Nigeria.

to electrical energy. Bell Laboratories invented the photovoltaic cell in 1954. Each cell generates only a small electric current, but large numbers of these cells wired together produce significant electricity. These cells are made primarily of silicon (also used in computers), the second most abundant element in Earth's crust. When the silicon is combined with one or more other materials, it exhibits distinctive electrical properties in the presence of sunlight, known as the photovoltaic effect. Electrons excited by the light move through the silicon, producing direct current (DC) electricity.

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

SOLAR POWERED ELECTRICITY

Solar power can be produced at a central station and distributed by an electric company, as coal- and nuclear-generated electricity are now supplied. However, with coal still relatively cheap and investment in nuclear facilities already substantial, public and private utility companies have had little interest in solar technology.

In developed countries, solar-generated electricity is used in spacecraft, light-powered calculators, and at remote sites where conventional power is unavailable, such as California's Mojave Desert. Solar energy is used primarily as a substitute for electricity in heating water. Rooftop devices collect, heat, and store water for apartment buildings in Israel and Japan and individual homes in the United States (Figure 11-56). The initial cost of installing a solar water heater is higher than hooking into the central system but may be justified if an individual plans to stay in the same house for a long time.

Electricity was popular in early motor vehicles. Of the 4,000 cars sold in the United States in 1900, 38 percent were powered by electricity, 40 percent by steam, and only 22 percent by gasoline. The electric car was especially popular in 1900 in large cities of the Northeast, such as New York and Philadelphia, where their relative quietness and cleanliness made them popular as taxicabs. Women also preferred electric cars because they were easier to start than gasoline- or steam-powered ones.

The main shortcomings of the electric car in the early 1900s remain unchanged a century later. Compared to gasoline power, the electric-powered vehicle has a more limited range and costs more to operate. Recharging the battery can take several hours. To address these issues, carmakers offer a variety of vehicles that combine electric and gasoline power. Hybrid vehicles conserve gasoline by running on electricity at low speeds. Other vehicles operate exclusively on battery-powered electricity and use the gasoline engine to recharge the battery (see Chapter 13).

▲ **FIGURE 11-56 SOLAR PANELS** Solar panels installed on apartment rooftops in the Old City of Jerusalem are used to heat water, which is stored in the adjacent tanks. The domes are the Church of the Holy Sepulchre, built at the site where Jesus is believed to have been crucified, buried, and resurrected (see Chapter 6).

In developing countries, the largest and fastest-growing market for photovoltaic cells includes the 2 billion people who lack electricity, especially residents of remote villages. For example, in sub-Saharan Africa, more homes have been electrified in recent years using photovoltaic cells than by hooking up to the central power grid. In Morocco, solar panels are sold in bazaars and open markets, next to carpets and tinware.

Solar energy currently accounts for only 0.3 quad BTU worldwide. The cost of cells must drop and their efficiency must improve for solar power to expand rapidly, with or without government support. Solar energy will become more attractive as other energy sources become more expensive. A bright future for solar energy is indicated by the fact that petroleum companies now own the major U.S. manufacturers of photovoltaic cells.

Air Pollution

LEARNING OUTCOME 11.3.8

Describe causes and effects of air pollution at global, regional, and local scales.

Industry is a major polluter of air, water, and land. People rely on air, water, and land to remove and disperse waste from factories as well as from other human activities. **Pollution** occurs when more waste is added than air, water, and land resources can handle.

At ground level, Earth's average atmosphere is made up of about 78 percent nitrogen, 21 percent oxygen, and less than 1 percent argon. The remaining 0.04 percent includes several trace gases, some of which are critical. **Air pollution** is a concentration of trace substances at a greater level than occurs in average air. Concentrations of these trace gases in the air can damage property and adversely affect the health of people, other animals, and plants.

Most air pollution is generated from factories and power plants, as well as from motor vehicles. Factories and power plants produce sulfur dioxides and solid particulates, primarily from burning coal. Burning petroleum in motor vehicles produces carbon monoxide, hydrocarbons, and nitrogen oxides.

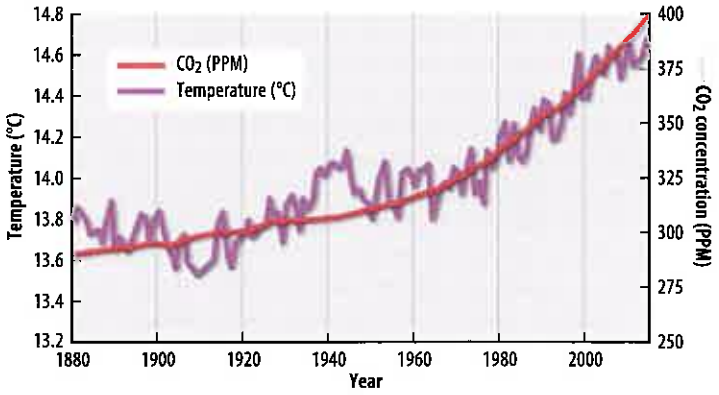
GLOBAL-SCALE AIR POLLUTION

Air pollution concerns geographers at three scales: global, regional, and local. Two global-scale issues are climate change and ozone damage.

CLIMATE CHANGE. The average temperature of Earth's surface increased by 0.89°C (1.6°F) between 1880 and 2014 (Figure 11-57). An international team of UN scientists has concluded that this temperature increase is directly linked to human actions, especially the burning of fossil fuels in factories and vehicles.

When fossil fuels are burned, carbon dioxide is discharged into the atmosphere. Plants and oceans absorb much of the discharge, but increased fossil fuel burning during the past 200 years has caused the level of carbon dioxide in the atmosphere to rise by more than one-fourth, according to the UN scientists (refer to Figure 11-57). A concentration of trace gases in the atmosphere can delay the return of some of the heat leaving Earth's surface heading for space, thereby raising Earth's temperatures. The increase in Earth's temperature, caused by carbon dioxide trapping some of the radiation emitted by the surface, is called the **greenhouse effect.**

As a country's per capita income increases, its per capita carbon dioxide emissions generally increase. Some of the wealthiest countries, located primarily in Europe, with GNI per capita between $30,000 and $50,000, show declines in pollution. However, the world's richest countries, including the United States and several countries in Southwest Asia, display the highest pollution levels (Figure 11-58).



▲ **FIGURE 11-57 CLIMATE CHANGE AND CO_2 CONCENTRATIONS** Since 1880, carbon dioxide concentration has increased by more than one-third, and Earth has warmed by about 1°C (2°F).

OZONE DAMAGE. **Ozone** is a gas that absorbs ultraviolet radiation in the stratosphere, a zone between 15 and 50 kilometers (9 to 30 miles) above Earth's surface. Were it not for the ozone in the stratosphere, UV rays would damage plants, cause skin cancer, and disrupt food chains.

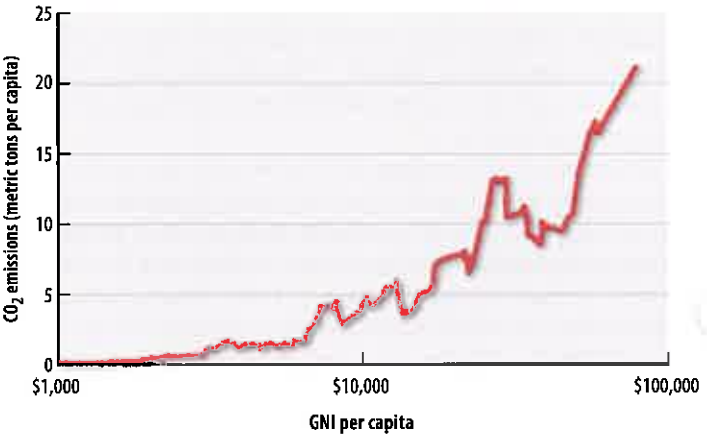
Earth's protective ozone layer is threatened by pollutants called **chlorofluorocarbons (CFCs).** CFCs such as Freon were once widely used as coolants in refrigerators and air conditioners. When they leak from these appliances, the CFCs are carried into the stratosphere, where they break down Earth's protective layer of ozone gas. In 2007, virtually all countries of the world agreed to cease using CFCs by 2020 in developed countries and by 2030 in developing countries.

PAUSE & REFLECT 11.3.8

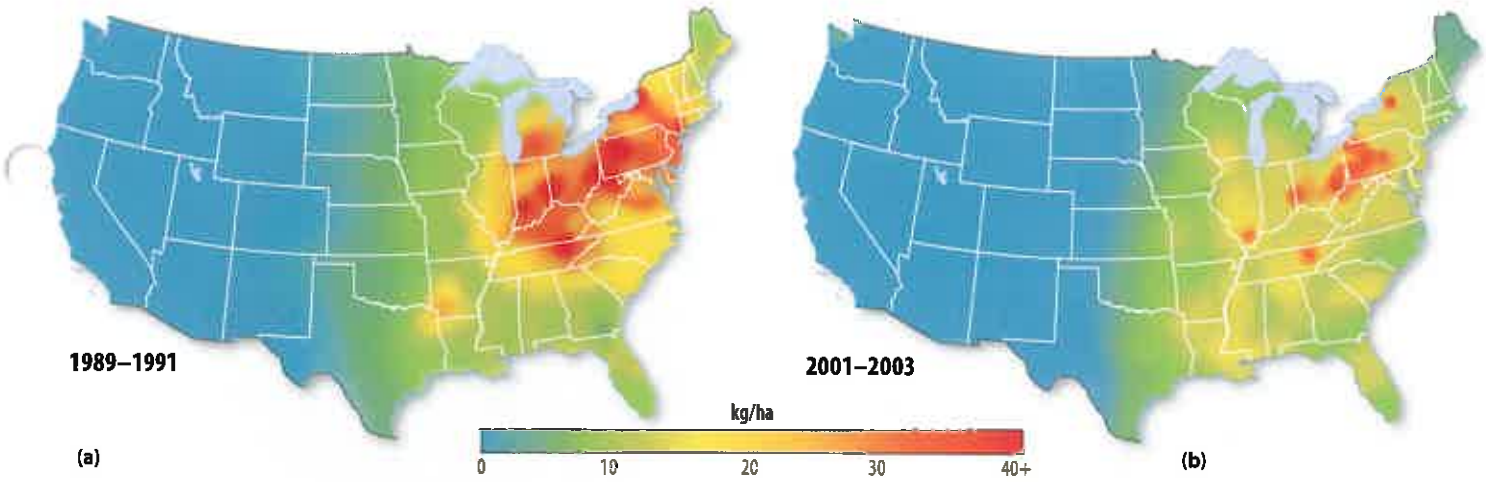
What gas is now most commonly used as a coolant instead of CFC? Use a search engine to find the answer.

REGIONAL-SCALE AIR POLLUTION

At the regional scale, air pollution may damage a region's vegetation and water supply through acid deposition. The world's three principal industrial regions are especially affected by acid deposition.



▲ **FIGURE 11-58 GNI AND POLLUTION**



▲ **FIGURE 11-59 ACID DEPOSITION** The worst effects of acid deposition are experienced further east than the principal sources of emissions.

Acid deposition is the accumulation of acids on Earth's surface. Sulfur oxides and nitrogen oxides, emitted by burning fossil fuels, enter Earth's atmosphere, combine with oxygen and water to form sulfuric acid and nitric acid, and are deposited on Earth's surface. **Acid precipitation** is the conversion of sulfur oxides and nitrogen oxides to acids that return to Earth as rain, snow, or fog. The acids can also be deposited in dust.

Acid precipitation damages lakes, killing fish and plants. On land, concentrations of acid in the soil can injure plants by depriving them of nutrients and can harm worms and insects. Buildings and monuments made of marble and limestone have suffered corrosion from acid rain. The United States has reduced sulfur dioxide emissions significantly in recent years.

Geographers are particularly interested in the effects of acid precipitation because the worst damage may not be experienced at the same location as the emission of the pollutants. Before they reach the surface, these acidic droplets might be carried hundreds of kilometers. Within the United States, the major generators of acid deposition are in Ohio and other industrial states along the southern Great Lakes, but the severest effects of acid rain are felt in several areas farther east (Figure 11-59).

LOCAL-SCALE AIR POLLUTION

At the local scale, air pollution is especially severe in places where emission sources are concentrated, such as in urban areas. The air above urban areas may be polluted because a large number of factories, motor vehicles, and other polluters emit residuals in a concentrated area.

Urban air pollution has three basic components:

- **Carbon monoxide.** Breathing carbon monoxide reduces the oxygen level in blood, impairs vision and alertness, and threatens those with breathing problems.
- **Hydrocarbons.** Hydrocarbons and nitrogen oxides in the presence of sunlight form **photochemical smog,** which causes respiratory problems, stinging in the eyes, and an ugly haze over cities.
- **Particulates.** These pollutants include dust and smoke particles. The dark plume of smoke from a factory stack and the exhaust of a diesel truck are examples of particulate emission.

According to the World Health Organization, most of the 20 most polluted cities are in South Asia (Figure 11-60). The city with the world's most polluted air (measured as the highest level of airborne particulates) is Delhi, India (Figure 11-61). The pollution level in Delhi is six times what the WHO considers the safe maximum.

▲ **FIGURE 11-60 CITIES WITH THE MOST POLLUTED AIR** Most are in South Asia.

▼ **FIGURE 11-61 AIR POLLUTION** Delhi, India.

Water Pollution

LEARNING OUTCOME 11.3.9

Compare and contrast point and nonpoint sources of water pollution.

Some manufacturers are heavy users of water. For example, a large amount of electricity is needed to separate pure aluminum from bauxite so aluminum producers often locate near sources of hydroelectric power (refer to Figure 11-50). Alcoa, the world's largest aluminum producer, owns dams in North Carolina and Tennessee.

Water serves many other human purposes. People must drink water to survive. It is used for cooking and bathing. Water provides a location for boating, swimming, fishing, and other recreational activities. It is home to fish and other aquatic life. Water is used for most economic activities, including agriculture and services, as well as manufacturing.

These uses depend on fresh, clean, unpolluted water. But that is not always available because people also use water for purposes that pollute it. Pollution is widespread because it is easy to dump waste into a river and let the water carry it downstream, where it becomes someone else's problem. Water can decompose some waste without adversely impacting other activities, but the volume of waste often exceeds the capacity that many rivers and lakes can accommodate.

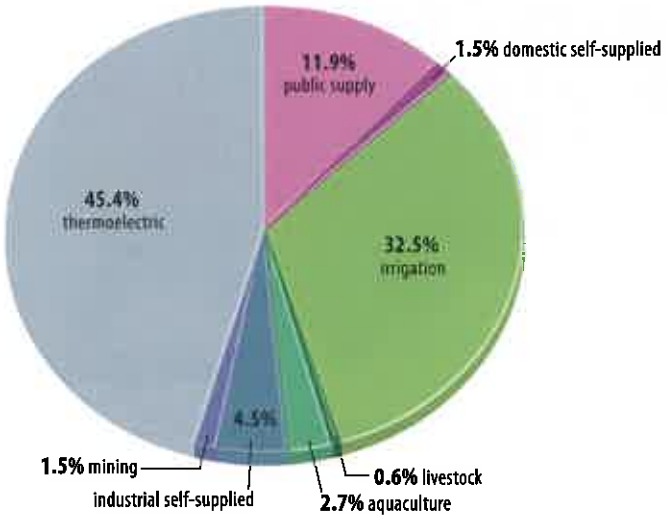
DEMAND FOR WATER

Humans use around 3.6 trillion cubic meters (950 billion gallons) of water per year, or around 500 cubic meters (132,000 gallons) per capita. The heaviest demand is for electricity, followed by agriculture and municipal sewage systems (Figure 11-62).

Water usage is either nonconsumptive or consumptive:

- **Nonconsumptive water usage** is use of water that is returned to nature as a liquid. Most industrial and municipal uses of water are nonconsumptive because the wastewater is primarily discharged into lakes and streams.
- **Consumptive water usage** is use of water that evaporates rather than being returned to nature as a liquid. Most agricultural uses are consumptive because the water is used primarily to supply plants that transpire it and therefore cannot be treated and reused.

North America has the world's highest per capita consumption of water, more than three times the worldwide average (Figure 11-63). Water usage is extremely high in the United States primarily because of agriculture rather than industry. U.S. farmers raise a large number of animals to meet the high demand for meat that the average American consumes, as discussed in Chapter 10. These animals drink a lot of water in their lifetimes. A large amount of water is also needed in U.S. agriculture to irrigate fields of crops.



▲ **FIGURE 11-62 WATER WITHDRAWAL BY USE**

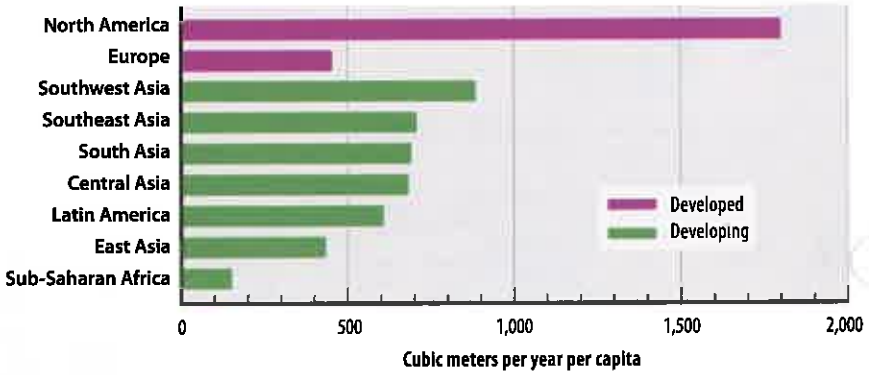
IMPACT ON AQUATIC LIFE

Polluted water can harm aquatic life. A commonly used measure of water pollution is **biochemical oxygen demand (BOD)**, which is the amount of oxygen required by aquatic bacteria to decompose a given amount of organic waste. Aquatic plants and animals consume oxygen, and so does the decomposing organic waste that humans dump in the water.

If too much waste is discharged into water, the water becomes oxygen starved, and fish die. This condition is typical when water becomes loaded with municipal sewage or industrial waste. The sewage and industrial pollutants consume so much oxygen that the water can become unlivable for normal plants and animals, creating a "dead" stream or lake (Figure 11-64).

Similarly, when runoff carries fertilizer from farm fields into streams or lakes, the fertilizer nourishes excessive aquatic plant production—a "pond scum" of algae—that consumes too much oxygen. Either type of pollution reduces the normal oxygen level, threatening aquatic plants and animals. Some of the residuals may become concentrated in the fish, making them unsafe for human consumption.

▼ **FIGURE 11-63 PER CAPITA WATER WITHDRAWL** North America has by far the highest per capita use of water.



▲ FIGURE 11-64 POLLUTED RIVER, INDIA

PAUSE & REFLECT 11.3.9

How might a change in the sources of energy used in factories help improve water quality?

POINT SOURCE POLLUTION

The sources of pollution can be divided into point sources and nonpoint sources:

- **Point source pollution** enters a body of water at a specific location.
- **Nonpoint source pollution** comes from a large, diffuse area.

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

▼ FIGURE 11-65 POINT SOURCE POLLUTION From a factory in Wolfen, Germany.

▲ FIGURE 11-66 NONPOINT SOURCE POLLUTION Delhi, India.

Point source water pollution originates from a specific point, such as a pipe from a wastewater treatment plant. These are the two main point sources of water pollution:

- **Water-using manufacturers.** Many factories and power plants use water for cooling and then discharge the warm water back into the river or lake. The warm water may not be polluted with chemicals, but it raises the temperature of the body of water it enters. Fish adapted to cold water, such as salmon and trout, might not be able to survive in the warmer water. Steel, chemicals, paper products, and food processing are major industrial polluters of water. Each requires a large amount of water in the manufacturing process and generates a lot of wastewater.
- **Municipal sewage.** In developed countries, sewers carry wastewater from sinks, bathtubs, and toilets to a municipal treatment plant, where most—but not all—of the pollutants are removed. The treated wastewater is then typically dumped back into a river or lake. In developing countries, sewer systems are rare, and wastewater often drains, untreated, into rivers and lakes. The drinking water, usually removed from the same rivers, may be inadequately treated as well. The combination of untreated water and poor sanitation makes drinking water deadly in some developing countries (Figure 11-65). Waterborne diseases such as cholera, typhoid, and dysentery are major causes of death.

NONPOINT SOURCE POLLUTION

Nonpoint sources usually pollute in greater quantities and are much harder to control than point sources of pollution (Figure 11-66). The principal nonpoint source is agriculture. Fertilizers and pesticides spread on fields to increase agricultural productivity are carried into rivers and lakes by irrigation systems or natural runoff. Expanded use of these products may help avoid a global food crisis, but it may destroy aquatic life by poiluting rivers and lakes.

Solid Waste Pollution

LEARNING OUTCOME 11.3.10

Describe principal strategies for reducing solid waste pollution.

The average American generates about 2 kilograms (4 pounds) of solid waste per day. Overall, residences generate around 60 percent of the solid waste and businesses 40 percent. Paper products, such as corrugated cardboard and newspapers, account for the largest share of solid waste in the United States, especially among residences and retailers. Manufacturers discard large quantities of metals as well as paper.

SANITARY LANDFILL

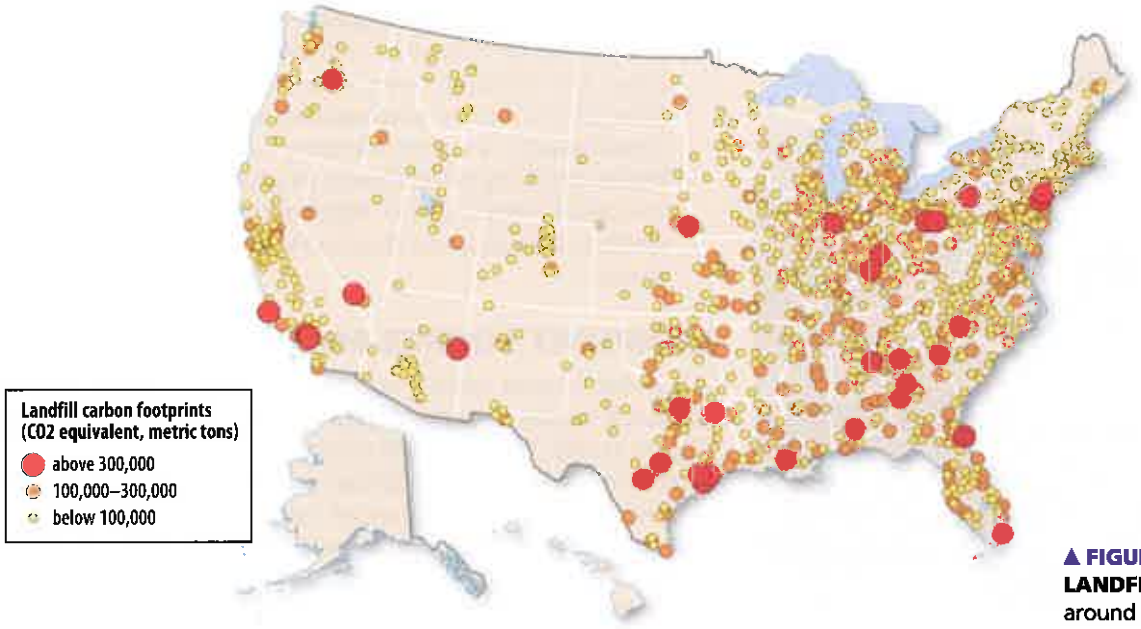
A **sanitary landfill** is the most common place for disposal of solid waste in the United States. More than one-half of the country's waste is trucked to landfills and buried under soil (Figure 11-67). This strategy is the opposite of our disposal of gaseous and liquid wastes: We disperse air and water pollutants into the atmosphere, rivers, and eventually the ocean, but we concentrate solid waste in thousands of landfills. Concentration would seem to eliminate solid-waste pollution, but it may only hide it—temporarily. Chemicals released by the decomposing solid waste can leak from the landfill into groundwater. This can contaminate water wells, soil, and nearby streams.

The use of landfills has declined sharply in the United States. The percentage of solid waste disposed in a landfill decreased from 89 percent in 1980 to 54 percent in 2010, and the number of landfills in the United States declined from 7,683 in 1986 to 1,908 in 2009. Thousands of small-town "dumps" have been closed and replaced by a small number of large regional ones. Better compaction methods, along with expansion in the land area of some of the large regional dumps, have resulted in expanded landfill capacity.

▲ **FIGURE 11-68 GREAT PACIFIC GARBAGE PATCH** Albatross birds stand beside plastic waste, part of the Great Pacific Garbage Patch that has washed ashore on Midway Atoll.

Some communities now pay to use landfills elsewhere. New York, New Jersey, and Illinois are the states that export the most solid waste. Pennsylvania, Virginia, and Michigan are the leading importers. Low transportation costs mean it is often cheaper to ship waste to states with landfills that charge low fees for accepting solid waste than to dispose of it locally.

The world's largest landfill is thought to be the Great Pacific Garbage Patch, which floats in the Pacific Ocean. It is estimated to be twice the size of the state of Texas. The patch is created by slow-moving currents that converge in the area. Trash is collected from all over the world. Plastic constitutes 90 percent of the trash floating in the oceans (Figure 11-68).



▲ **FIGURE 11-67 SANITARY LANDFILLS** The United States has around 1,908 sanitary landfills.

HAZARDOUS WASTE

Disposing of hazardous waste is especially difficult. Hazardous wastes include heavy metals (including mercury, cadmium, and zinc), PCB oils from electrical equipment, cyanides, strong solvents, acids, and caustics. These may be unwanted byproducts generated in manufacturing or waste to be discarded after usage.

According to the toxic waste inventory published by the U.S. Environmental Protection Agency (EPA), 1.25 billion kilograms (2.75 billion pounds) of toxic chemicals were released into the land in 2013 by the 100 most polluting sites (Figure 11-69). The 4 largest polluters were Red Dog Operations zinc mine in Kotzebue, Alaska; Newmont Mining Corporation's Twin Creeks gold and copper mine in Golconda, Nevada; BHP Billiton's San Manuel copper mine in San Manuel, Arizona; and Kennecott Utah Copper's concentrator in Copperton, Utah.

If poisonous industrial residuals are not carefully placed in protective containers, the chemicals may leach into the soil and contaminate groundwater or escape into the atmosphere. Breathing air or consuming water contaminated with toxic wastes can cause cancer, mutations, chronic ailments, and even immediate death.

PAUSE & REFLECT 11.3.10

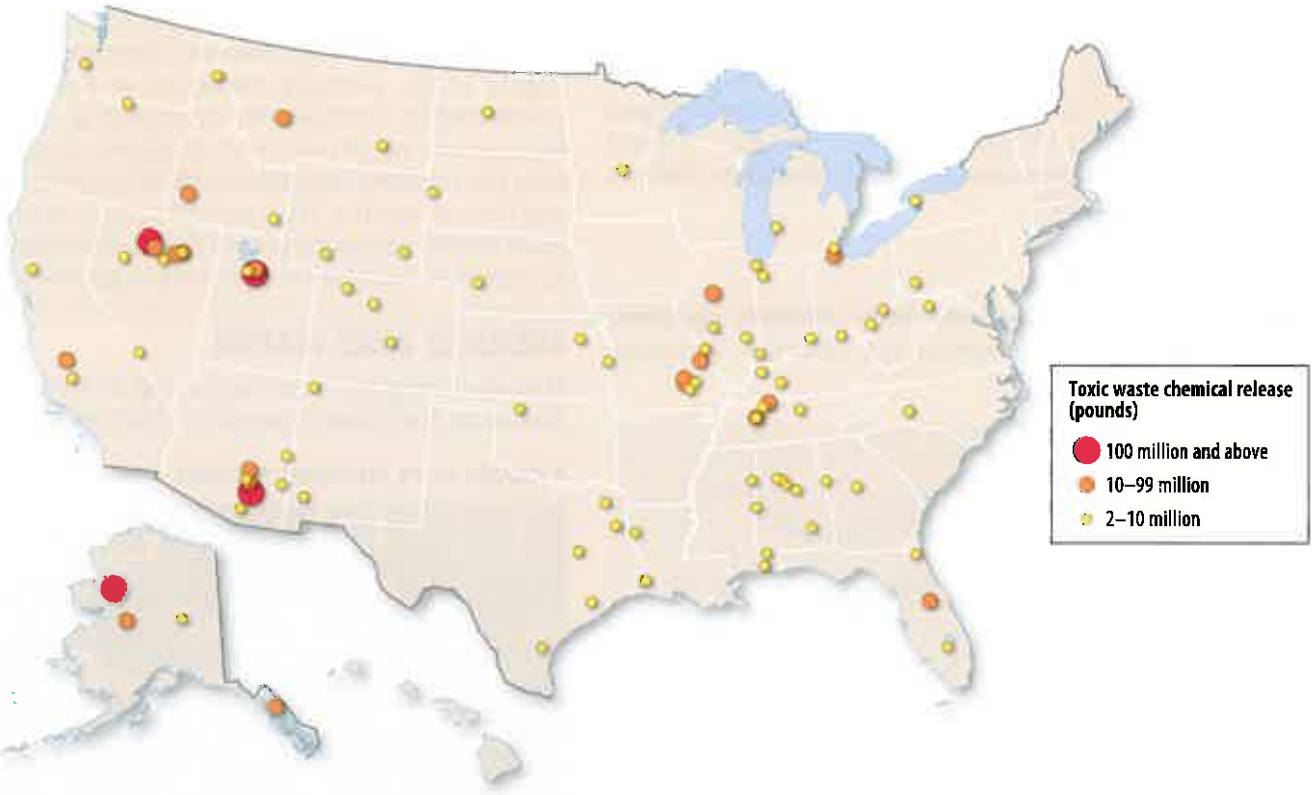
Where does your solid waste go?

CHECK-IN KEY ISSUE 3

Why Do Industries Face Resource Challenges?

- ✔ **Supplies of the three fossil fuels—coal, natural gas, and petroleum—are not distributed uniformly.**
- ✔ **Industries are one of four major users of energy, along with transportation, residences, and commercial activities.**
- ✔ **Alternative energy sources include hydroelectricity, wind, nuclear, solar, and geothermal.**
- ✔ **Industry is a major polluter of air, land, and water.**
- ✔ **Air pollution can occur at global, regional, and local scales.**
- ✔ **Water pollution can have point or nonpoint sources.**
- ✔ **Solid waste that is "thrown away" is either transported to landfills or incinerated.**

▼ **FIGURE 11-69 TOXIC CHEMICAL RELEASE SITES** Ohio has the most sites, although the largest sites are mines in the West.



KEY ISSUE 4

Why Are Industries Changing Locations?

- Emerging Industrial Regions
- Industrial Change in Developed Countries
- Skilled or Unskilled Labor?
- Recycling and Remanufacturing

LEARNING OUTCOME 11.4.1

Explain reasons for the emergence of new concentrations of industries.

Industry is on the move around the world. Site factors, especially labor costs, have stimulated industrial growth in new regions, both internationally and in developed regions. Situation factors, especially proximity to growing markets, have also played a role in the emergence of new industrial regions.

Emerging Industrial Regions

In 1970, nearly one-half of world industry was in Europe and nearly one-third was in North America; now these two regions account for only one-fourth each. Industry's share of total economic output has steadily declined in developed countries since the 1970s (Figure 11-70). The share of world industry in other regions has increased—from one-sixth in 1970 to one-half in 2010.

OUTSOURCING

Transnational corporations have been especially aggressive in using low-cost labor in developing countries. To remain competitive in the global economy, they carefully review their production processes to identify steps that can be performed by low-paid, low-skilled workers in developing countries.

Despite the greater transportation cost, transnational corporations can profitably transfer some work to developing countries, given their substantially lower wages compared to those in developed countries. At the same time, operations that require highly skilled workers remain in factories in developed countries. This selective transfer of some jobs to developing countries is known as the **new international division of labor.**

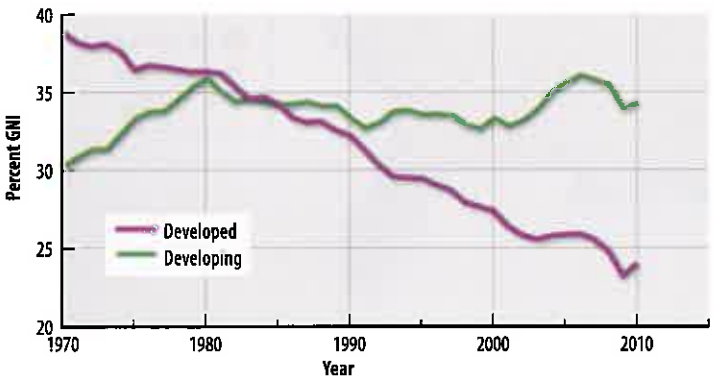
Transnational corporations allocate production to low-wage countries through **outsourcing,** which is turning over much of the responsibility for production to independent suppliers. Outsourcing has had a major impact on the distribution of manufacturing because each step in the production process is now scrutinized closely in order to determine the optimal location.

Outsourcing contrasts with the approach typical of traditional mass production, called **vertical integration,** in which a company controls all phases of a highly complex production process. Vertical integration was traditionally regarded as a source of strength for manufacturers because it gave them the ability to do and control everything. Carmakers once made nearly all their own parts, for example, but now most of this operation is outsourced to other companies that are able to make the parts cheaper and better.

Outsourcing is especially important in the electronics industry. The world's largest electronics contractor is Foxconn, a major supplier of chips and other electronics components for such companies as Apple and Intel. Foxconn employs around 1 million people in China, including several hundred thousand at its Foxconn City complex in Shenzhen (Figure 11-71). Working conditions at Foxconn have been scrutinized by Chinese and international organizations. A large percentage of Foxconn's employees live in dormitories near the factories, and they work long hours for low wages and limited benefits. More controversial is an internship program employing young people during the summers that critics charge is a way for the company to get free child labor.

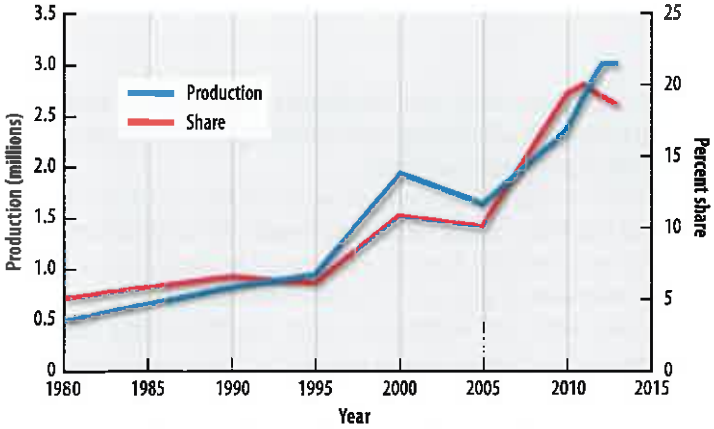
MEXICO AND NAFTA

Manufacturing has been increasing in Mexico. The North American Free Trade Agreement (NAFTA), which went into

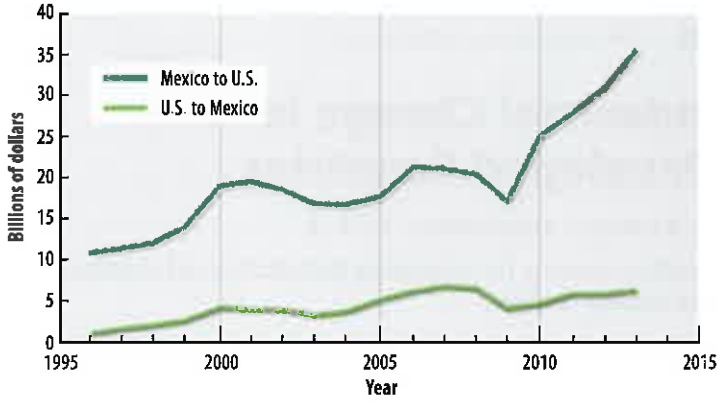


▲ FIGURE 11-70 **MANUFACTURING VALUE AS A PERCENTAGE OF GNI** Manufacturing has accounted for a higher share of GNI in developing countries than in developed countries since the 1990s.

▼ FIGURE 11-71 **FOXCONN FACTORY** Jiangsu Province, China.



▲ **FIGURE 11-72 VEHICLE PRODUCTION IN MEXICO**



▲ **FIGURE 11-73 U.S.–MEXICO TRADE IN VEHICLES**

effect in 1994, eliminated most barriers to moving goods among Mexico, the United States, and Canada. Because it is the nearest low-wage country to the United States, Mexico attracts industries concerned with both a site factor (low-cost labor) and a situation factor (proximity to U.S. markets).

Nearly all of the growth of motor vehicle production in North America, for example, has been located in Mexico rather than the United States or Canada (Figures 11-72 and 11-73). Plants in Mexico near the U.S. border are known as **maquiladoras.** The term originally applied to a tax when Mexico was a Spanish colony. Under U.S. and Mexican laws, companies receive tax breaks if they ship materials from the United States, assemble components at a maquiladora plant in Mexico, and export the finished product back to the United States. More than 1 million Mexicans are employed at more than 3,000 maquiladoras.

Integration of North American industry has generated fear in the United States and Canada. Labor leaders fear that more manufacturers will relocate production to Mexico to take advantage of lower wage rates. Labor-intensive industries such as food processing, electronics, and textile manufacturing are especially attracted to regions where prevailing wage rates are lower.

Environmentalists fear that NAFTA encourages firms to move production to Mexico because laws there governing air- and water-quality standards are less stringent than in the United States and Canada. Mexico has adopted regulations to reduce air pollution in Mexico City, but environmentalists charge that environmental protection laws are still not strictly enforced in Mexico.

Mexico faces its own challenges. Although much lower than in the United States, Mexican wages are higher than in China. Despite the higher site costs, however, Mexico still competes effectively with China because it has much lower shipping costs to the United States and Europe than does China. Mexico has also signed free trade agreements with many other countries in addition to the United States.

PAUSE & REFLECT 11.4.1

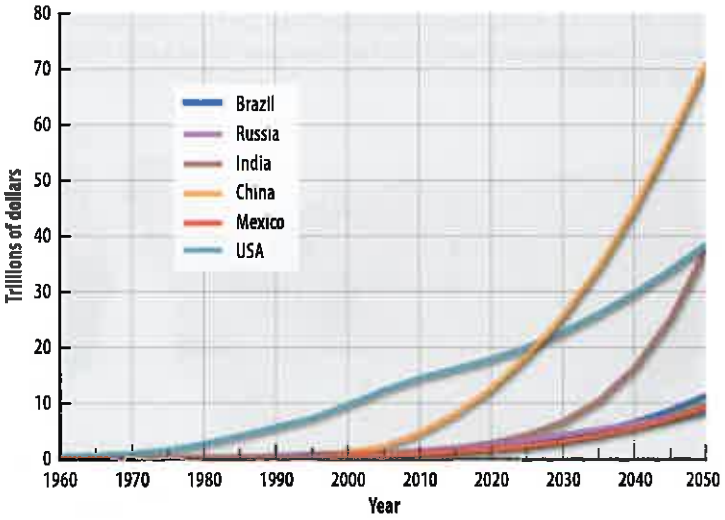
Take a close look at an iPhone (yours or a friend's or relation's). Can you find any evidence that it was made at Foxconn in China?

BRIC COUNTRIES

Much of the world's future growth in manufacturing is expected to cluster in a handful of countries known as BRIC, which is an acronym coined by the investment banking firm Goldman Sachs for Brazil, Russia, India, and China. The foreign ministers of these four countries started meeting in 2006.

The four BRIC countries together encompass one-fourth of the world's land area and contain 3 billion of the world's 7 billion inhabitants, but the four countries combined account for only one-sixth of world GDP (Figure 11-74). Their economies rank second (China), seventh (Brazil), ninth (Russia), and eleventh (India). China is expected to pass the United States as the world's largest economy around 2020, and India is expected to become second around 2050.

China and India have the two largest labor forces, whereas Russia and Brazil are especially rich in inputs critical for industry. China, India, and Russia could form a contiguous industrial region, but long-standing animosity among them has limited their economic interaction so far. Brazil, is of course, not contiguous to the other three. Still, the BRIC concept is that if the four giants work together, they can be the world's dominant industrial bloc in the twenty-first century.



▲ **FIGURE 11-74 GDP FOR BRIC COUNTRIES, MEXICO, AND THE UNITED STATES** China is expected to have the world's largest GDP during the 2020s, and India is expected to be second in the 2050s.

Industrial Change in Developed Countries

LEARNING OUTCOME 11.4.2

Explain reasons for changing distribution of industry in developed regions.

In developed regions, industry is shifting away from the traditional industrial areas of northwestern Europe and the northeastern United States. In the United States, industry has shifted from the Northeast toward the South and West. In Europe, government policies have encouraged relocation toward economically distressed peripheral areas.

INTRAREGIONAL SHIFTS IN NORTH AMERICA

The United States lost 2.3 million manufacturing jobs between 1950 and 2015. The Northeast lost 3.7 million manufacturing jobs during the period, and the Great Lakes states lost 1.6 million. On the other hand, the South added 1.3 million manufacturing jobs, and the far western states gained 1.1 million (Figure 11-75).

Industrialization during the late nineteenth and early twentieth centuries largely bypassed the South, which had not recovered from losing the Civil War. The South lacked the infrastructure needed for industrial development: Road and rail networks were less intensively developed in the South, and electricity was less common than in the North. As a result, the South was the poorest region of the United States. Industrial growth in the South since the 1930s has been stimulated in part by government policies to reduce historical disparities. The Tennessee Valley Authority brought electricity to much of the rural South, and roads were constructed in previously inaccessible sections of the Appalachians, the Piedmont, and the Ozarks. Air-conditioning made living and working in the South more tolerable during the summer.

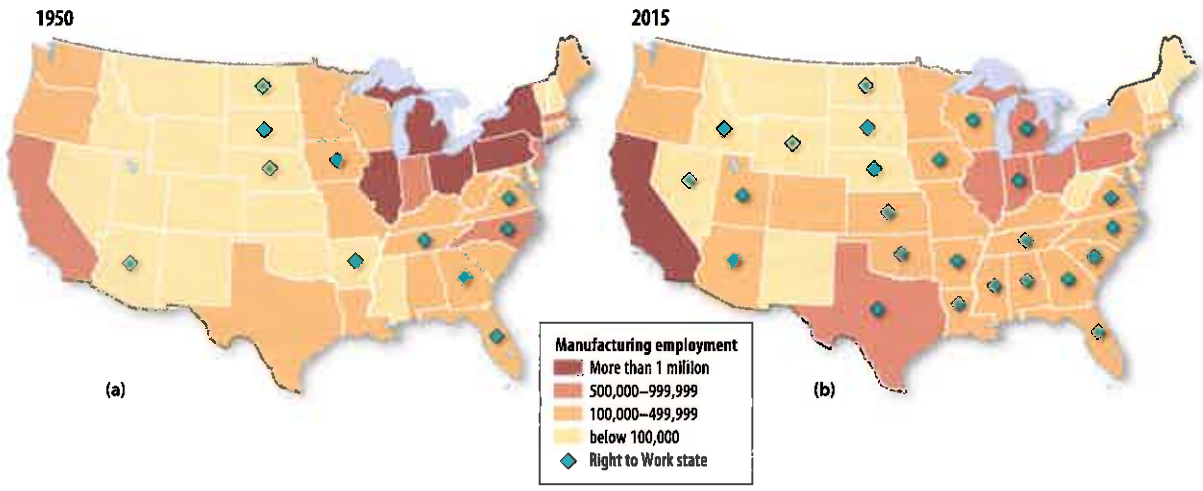
Motor vehicle production is an example of an industry that has been attracted to the South. Most production is located in a corridor known as auto alley formed by north-south interstate highways 65 and 75 between Michigan and Alabama, with an extension into southwestern Ontario (Figure 11-76). Newer plants are in the southern portion of auto alley.

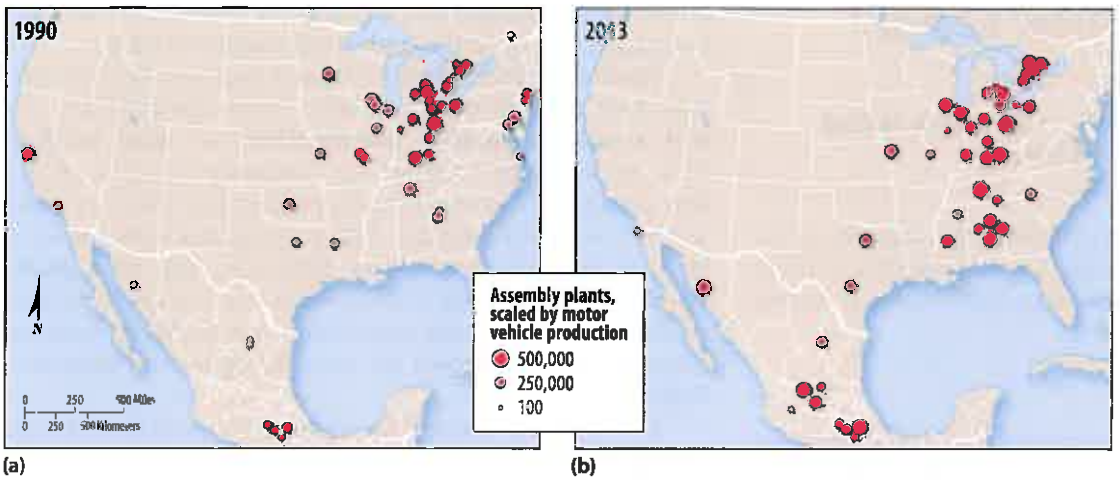
Steel, textiles, tobacco products, and furniture industries have become dispersed through smaller communities in the South, many in search of a labor force willing to work for less pay than in the North and forgo joining a union. The Gulf Coast has become an important industrial area because of its access to oil and natural gas. Along the Gulf Coast are oil refining, petrochemical manufacturing, food processing, and aerospace product manufacturing.

The principal lure for many manufacturers has been right-to-work laws. A **right-to-work law** requires a factory to maintain a "open shop" and prohibits a "closed shop." In a closed shop, a company and a union agree that everyone must join the union to work in the factory. In an open shop, a union and a company may not negotiate a contract that requires workers to join a union as a condition of employment.

Twenty-five U.S. states (refer to Figure 11-75) have right-to-work laws that make it much more difficult for unions to organize factory workers, collect dues, and bargain with employers from a position of strength. Right-to-work laws send a powerful signal that antiunion attitudes will be tolerated and perhaps even actively supported. As a result, the percentage of workers who are members of a union is much lower in the South than elsewhere in the United States. More importantly, the region has been especially attractive for companies working hard to keep out unions altogether.

FIGURE 11-75 CHANGING DISTRIBUTION OF U.S. INDUSTRY (a) 1950. (b) 2015.
Manufacturing has declined in the Northeast and Great Lakes states while increasing in the South and West.





◀ **FIGURE 11-76 MOTOR VEHICLE PRODUCTION IN NORTH AMERICA (a)** 1990. **(b)** 2013. The size of the circles represents the volume of production at the assembly plant.

INTRAREGIONAL SHIFTS IN EUROPE

Manufacturing has diffused from traditional industrial centers in northwestern Europe toward Southern and Eastern Europe. To some extent, European government policies have encouraged this industrial relocation. The European Union Structural Funds provide assistance to what it calls convergence regions, competitive, and cooperative regions:

- Convergence regions are primarily in Eastern and Southern Europe, where incomes lag behind Europe's average.
- Competitive and employment regions are primarily Western Europe's traditional core industrial areas, which have experienced substantial manufacturing job losses in recent years.
- Territorial cooperation regions are near borders between European Union countries and neighboring countries.

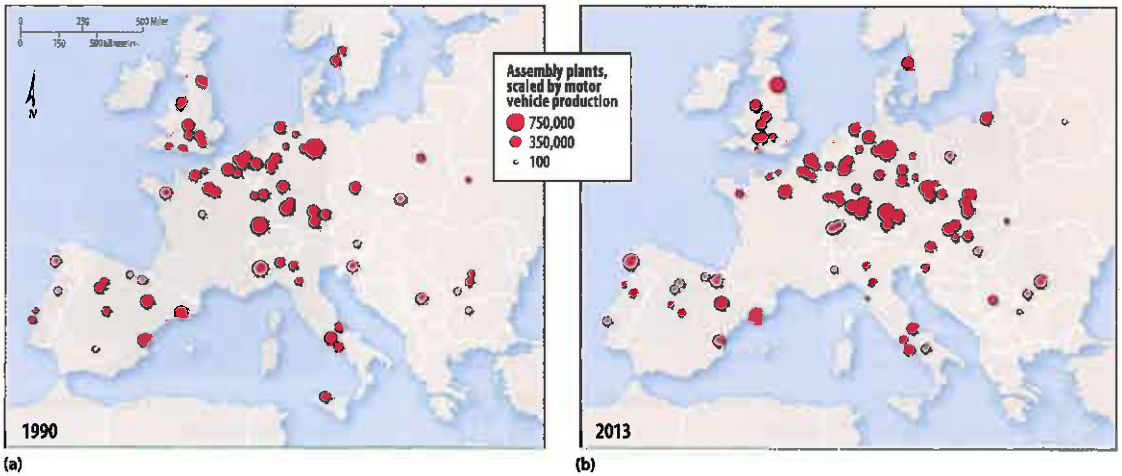
The Western European country with the most rapid manufacturing growth during the late twentieth century was Spain, especially after its admission to the European Union in 1986. Until then, Spain's manufacturing growth had been impeded by physical and political isolation. Spain's motor-vehicle industry has grown into the second largest in Europe, behind only Germany's, although it is entirely foreign owned. Spain's leading industrial area is Catalonia, in the northeast, centered on the city of Barcelona. The region has the country's largest motor-vehicle plant and is the center of Spain's textile industry as well.

Several European countries situated east of Germany and west of Russia have become major centers of industrial investment since the fall of communism in the early 1990s. Poland, Czechia, Hungary, and Slovakia have had the most industrial development. Central Europe offers manufacturers an attractive combination of two important site and situation factors: labor and market proximity. Central Europe's workers offer manufacturers good value for money; they are less skilled but much cheaper than in Western Europe, and they are more expensive but much more skilled than in Asia and Latin America. At the same time, the region offers closer proximity to the wealthy markets of Western Europe than other emerging industrial centers. Central Europe has attracted an increasing share of the region's motor vehicle production (Figure 11-77).

PAUSE & REFLECT 11.4.2

Motor vehicle production has increased in Turkey and Morocco. What might be advantages and challenges of producing vehicles in these countries instead?

▶ **FIGURE 11-77 MOTOR VEHICLE PRODUCTION IN EUROPE (a)** 1990. **(b)** 2013. The size of the circles represents the volume of production at the assembly plant.



Skilled or Unskilled Labor?

LEARNING OUTCOME 11.4.3

Understand the attraction of locations with skilled labor and those with unskilled labor.

Many manufacturers are torn between the benefits of locating in regions with low-skilled low-cost labor and those with highly skilled higher-cost labor (See Debate It feature and Doing Geography feature).

SKILLED LABOR

Given the strong lure of low-cost labor in new industrial regions, why would any industry locate in one of the traditional regions, especially in the northeastern United States or northwestern Europe? Two location factors influence industries to remain in these traditional regions: availability of skilled labor and rapid delivery to market.

Henry Ford boasted that he could take people off the street and put them to work with only a few minutes of training. That has changed for some industries, which now want skilled workers instead. The search for skilled labor has important geographic implications because it is an asset found principally in the traditional industrial regions.

Traditionally, factories assigned each worker one specific task to perform repeatedly. Some geographers call this approach **Fordist production**, or mass production, because the Ford Motor Company was one of the first companies to organize its production this way early in the twentieth century. Many industries now follow a lean, or flexible, production approach. The term **post-Fordist production** is sometimes used to describe lean production, in contrast with Fordist production. Another carmaker is best known for pioneering lean production: Toyota.

Four types of work rules distinguish post-Fordist lean production:

- **Teams.** Workers are placed in teams and told to figure out for themselves how to perform a variety of tasks. Companies are locating production in communities where workers are willing to adopt more flexible work rules.
- **Problem solving.** A problem is addressed through consensus after consulting with all affected

DEBATE IT! Should the U.S. government buy domestic- or foreign-made clothes?

The U.S. government shops for clothing bargains, wherever they can be found in the world. Most uniforms as well as clothing sold in military bases are made in either Latin America or Asia rather than in the United States.

BUY CLOTHING ANYWHERE

- Buying overseas saves taxpayers money.
- It's hard to find U.S. manufacturers for all of the government's needs.
- The government is monitoring conditions in the factories where it gets the clothes.

▲ FIGURE 11-78 WHERE CLOTHING BOUGHT BY THE U.S. GOVERNMENT IS MADE

BUY U.S.–MADE CLOTHING

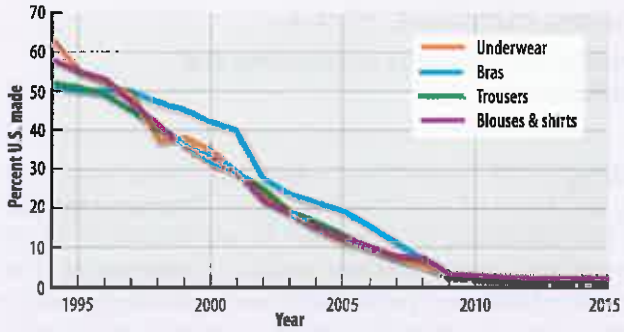
- Supporting U.S. businesses will create jobs in the United States.
- The government should set an example by buying domestic products.
- Workplace conditions are poor in some overseas factories.

▲ FIGURE 11-79 CLOTHING WORKERS IN BANGLADESH

DOING GEOGRAPHY National Origin of Clothing

Most clothing sold in the United States has been assembled in other countries. The top five countries of origin for clothing sold in the United States are China, Vietnam, Bangladesh, Indonesia, and Honduras.

As recently as the 1990s, most clothing sold in the United States was assembled in the United States, but now very little is U.S. made (Figure 11-80). As apparel from other countries became less expensive and less complicated to import into the United States, mills in the Southeast paying wages of $10 to $15 per hour were unable to compete with manufacturers in countries paying less than $1 per hour. The number of clothing workers in the United States declined from 900,000 in 1990 to 500,000 in 2000 and to 150,000 in 2010.



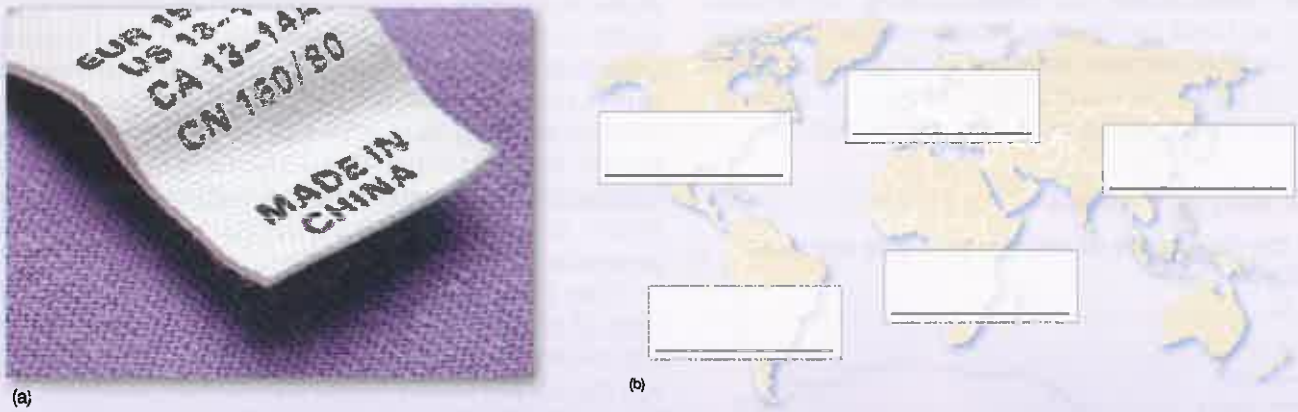
▲ **FIGURE 11-80 DOMESTIC AND IMPORTED U.S. CLOTHING** The percentage of clothing sold in the United States that was made in the United States has declined from around 50 percent in the 1990s to 3 percent today.

What's Your Industrial Geography?

National Origin of Your Clothing

Clothing sold in the United States has a label showing national origin (Figure 11-81a).

1. Take a look at the labels in 10 of your t-shirts. For each t-shirt, record the world region in which it was made (Africa, Asia, Europe, Latin America, or North America). Record the total number of t-shirts made in each of the five regions.
2. Sum the total t-shirts made in each of the five regions. Which region has the highest number? Which has the lowest?
3. Combine the results of everyone in your class. Record on a world map, such as Figure 11-81b. How do your results compare with those of the overall class?
4. Which of the three developing regions (Africa, Asia, or Latin America) has the highest total? Which has the lowest total? What might account for the sharp difference between these developing regions?



(a) (b)

▲ **FIGURE 11-81 PLACE OF ORIGIN OF YOUR CLOTHING** **(a)** Example of a clothing label. **(b)** Regional origin of your t-shirts.

parties rather than through filing a complaint or grievance.

- **Leveling.** Factory workers are treated alike, and managers and veterans do not get special treatment; they wear the same uniform, eat in the same cafeteria, park in the same lot, and participate in the same athletic and social activities.
- **Productivity.** Factories have become more productive through introduction of new machinery and processes. Rather than requiring physical strength, these new machines and processes require skilled operators, typically with college degrees.

Recycling and Remanufacturing

LEARNING OUTCOME 11.4.4

Understand the concepts of recycling and remanufacturing.

Recycling is the separation, collection, processing, marketing, and reuse of unwanted material. **Remanufacturing** is the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts. Both are increasingly used in industry as ways to promote a more sustainble production process.

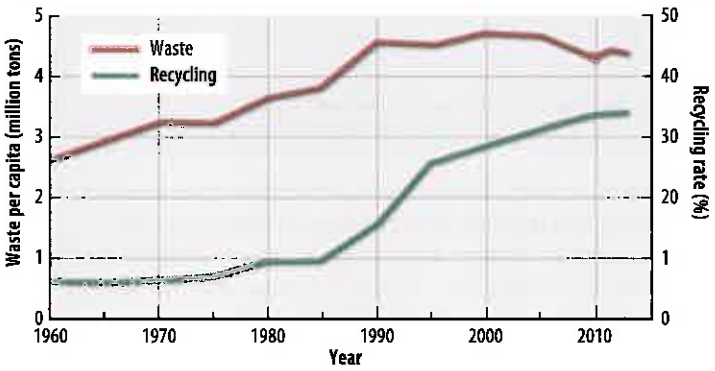
RECYCLING

Recycling increased in the United States from 7 percent of all solid waste in 1970 to 10 percent in 1980, 17 percent in 1990, and 34 percent in 2013 (Figure 11-82). As a result of recycling, about 87 million of the 254 million tons of solid waste generated in the United States in 2013 did not have to go to landfills and incinerators, compared to 34 million of the 200 million tons generated in 1990.

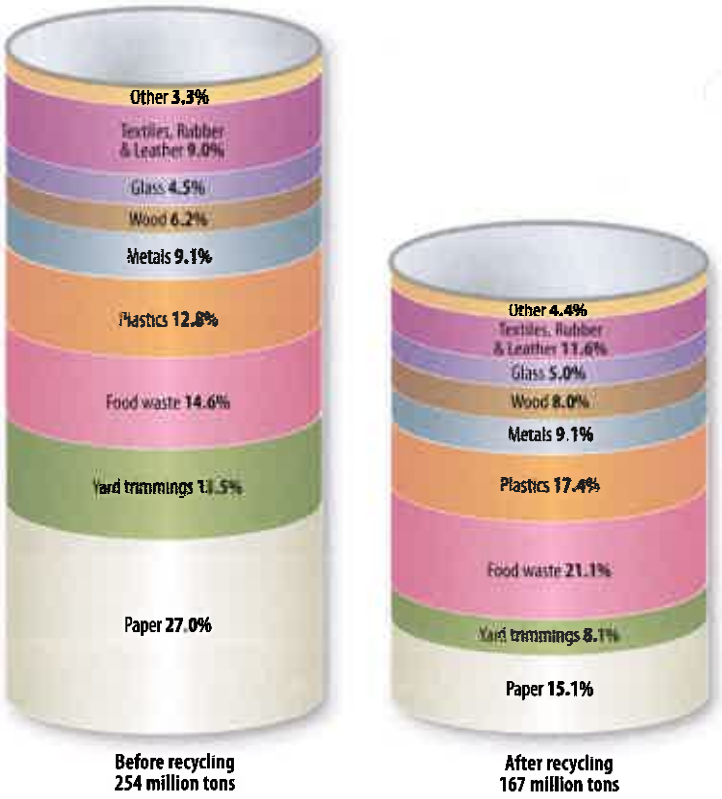
The percentage of materials recovered by recycling varies widely by product: 50 percent of paper products and 24 percent of yard trimmings are recycled, compared to less than 10 percent for other sources of solid waste (Figure 11-83). Materials that would otherwise be "thrown away" are collected and sorted, in four principal ways: Curbside programs, drop-off centers, buy-back centers, and deposit programs. Regardless of the collection method, recyclables are sent to a materials recovery facility to be sorted and prepared as marketable commodities for manufacturing. Recyclables are bought and sold just like any other commodity; typical prices per ton in recent years have been $300 for clear plastic bottles, $30 for clear glass, and $100 for newspaper. Prices for the materials change and fluctuate with the market.

PAUSE & REFLECT 11.4.4

Which of the four types of recycling do you use most often? Why?



▲ **FIGURE 11-82 RECYCLING IN THE UNITED STATES** Recycling has increased from around 10 percent in 1980 to around 35 percent today.



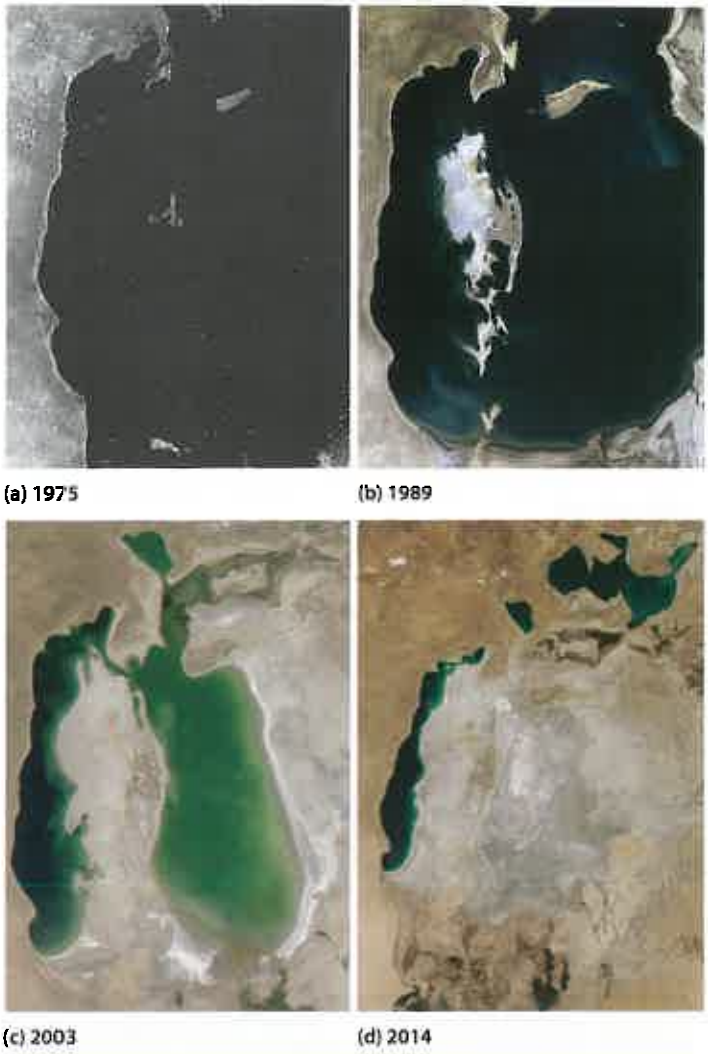
▲ **FIGURE 11-83 SOURCES OF SOLID WASTE BEFORE AND AFTER RECYCLING** Around one-half of paper and one-fourth of yard waste are recycled, whereas 10 percent of other sources are recycled.

REMANUFACTURING

Recycled materials can be remanufactured into new products. Four major manufacturing sectors accounted for more than half of the recycling activity: paper mills, steel mills, plastic converters, and iron and steel foundries (see Sustainability & Our Environment feature). Common household items that contain remanufactured materials include newspapers and paper towels; aluminum, plastic, and glass soft-drink containers; steel cans; and plastic laundry detergent bottles. Recycled materials are also used in such industrial applications as recovered glass in roadway asphalt ("glassphalt") and recovered plastic in carpet, park benches, and pedestrian bridges.

One of the world's most extreme instances requiring a form of remanufacturing is the Aral Sea, divided between the countries of Kazakhstan and Uzbekistan. The Aral Sea was the world's fourth-largest lake in 1960, at 68,000 square kilometers (26,000 square miles). It had shrunk to approximately 5,000 square kilometers (2,000 square miles) in 2010, and it could disappear altogether by 2020 (Figure 11-84). The shrinking has been captured in aerial photos and satellite imagery.

The Aral Sea died because beginning in 1954, the Soviet Union diverted its tributary rivers, the Amu Dar'ya and the Syr Dar'ya, to irrigate cotton fields. Ironically, the cotton now is withering because winds pick up salt from the exposed lakebed and deposit it on the cotton fields. Carp, sturgeon, and other fish species have disappeared; the last



◀ FIGURE 11-84 **THE DISAPPEARING ARAL SEA** (a) 1975. (b) 1989. (c) 2003. (d) 2014.

fish died in 1983. Large ships lie aground in salt flats that were once the lakebed, outside abandoned fishing villages that now lay tens of kilometers from the rapidly receding shore.

CHECK-IN KEY ISSUE 4

Why Are Industries Changing Locations?

- ✔ **Industry is growing in places that are not part of traditional industrial regions, primarily because of low-cost labor.**
- ✔ **Within developed regions, industry is also growing in nontraditional locations.**

SUSTAINABILITY & OUR ENVIRONMENT

Remanufacturing

Remanufacturing contributes to a more sustainable environment. The principal challenge is to increase its economic sustainability.

- **Paper.** Most types of paper can be recycled. Newspapers have been recycled profitably for decades, and recycling of other paper, especially computer paper, is growing. Rapid increases in virgin paper pulp prices have stimulated construction of more plants capable of using waste paper. The key to recycling is collecting large quantities of clean, well-sorted, uncontaminated, dry paper.
- **Plastic.** The plastic industry has developed a system of numbers marked inside triangles. Symbols 2 (milk jugs), 4 (shopping bags), and 5 (such as yogurt containers) are considered to be safest for recycling. The plastics in symbols 3 (such as food wrap), 6 (Styrofoam), and 7 (such as iPad cases) may contain carcinogens. Symbol 1 (soda and water bottles) can allow bacteria to accumulate.
- **Aluminum.** The principal source of recycled aluminum is beverage containers. Aluminum cans began to replace glass bottles for beer during the 1950s and for soft drinks during the 1960s. Aluminum scrap is readily accepted for recycling, although other metals are rarely accepted.

▲ FIGURE 11-85 **REMANUFACTURING** Junked cars await shredding so that the steel can be reused.

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

Summary & Review

KEY ISSUE 1

Where is industry distributed?

Industry is not distributed uniformly around the world. It is highly dependent on availability of energy, especially fossil fuels. The concept of manufacturing goods in a factory originated with the Industrial Revolution in the United Kingdom. Most of the world's industry is clustered in the three regions: Europe, North America, and East Asia.

THINKING GEOGRAPHICALLY

1. What situation and site factors hurt the ability of the United Kingdom to maintain the leadership in industry that it gained in the nineteenth century?

▲ FIGURE 11-86 CLOSED FACTORY, UNITED KINGDOM

KEY ISSUE 2

Why are situation and site factors important?

A company ordinarily considers a combination of situation and site factors. Situation factors involve transporting inputs into a factory and transporting manufactured goods to the markets. The three site factors are labor, capital, and land. Inputs and products are transported by ship, rail, truck, or air. The optimal choice depends on the distance something is being transported.

THINKING GEOGRAPHICALLY

2. Volkswagen received $577 million in government incentives to locate a factory in Chattanooga, Tennessee, in 2012. Do you think it's worth it for governments to provide large incentives like this? Why or why not?

▲ FIGURE 11-87 VOLKSWAGEN ASSEMBLY PLANT, CHATTANOOGA, TENNESSEE

KEY ISSUE 3

Why do industries face resource challenges?

Energy and other resources are critical for industry. Energy is currently derived primarily through the three fossil fuels: coal, petroleum, and natural gas. Reserves are highly concentrated in a handful of countries. Demand for energy comes from four main sources: industries, transportation, homes, and commercial activities. Alternatives to the fossil fuels include hydroelectric, nuclear, wind, geothermal, and solar. Industry is a major polluter of air, water, and land.

THINKING GEOGRAPHICALLY

3. What strategies does your community employ to encourage recycling? What additional strategies might be effective in your community? Why?

▲ FIGURE 11-88 RECYCLING, OAK PARK, ILLINOIS

KEY ISSUE 4

Why are industries changing locations?

The location of manufacturing has changed. Industry is increasing in some developing countries and in some areas within developed regions. Site factors, especially labor costs, have stimulated industrial growth in new regions, especially the BRIC countries. Within North America and Europe, manufacturing is growing in areas where it had not traditionally clustered.

THINKING GEOGRAPHICALLY

4. What has been the impact on Canada of the changes in the distribution of vehicle assembly plants in North America (refer to Figure 11-76)?
5. Why might situation and site factors be placing Canadian plants at a disadvantage compared to those in Mexico?

▲ FIGURE 11-89 TRUCKS FROM MEXICO BACKED UP AT THE U.S. BORDER

KEY TERMS

Acid deposition *(p. 415)* The accumulation of acids on Earth's surface.

Acid precipitation *(p. 415)* Conversion of sulfur oxides and nitrogen oxides to acids that return to Earth as rain, snow, or fog.

Active solar energy *(p. 412)* Solar radiation captured with photovoltaic cells that convert light energy to electrical energy.

Air pollution *(p. 414)* Concentration of trace substances, such as carbon monoxide, sulfur dioxide, nitrogen oxides, hydrocarbons, and solid particulates, at a greater level than occurs in average air.

Animate power *(p. 385)* Power supplied by animals or by people.

Biomass fuel *(p. 385)* Fuel derived from wood, plant material, or animal waste.

Biochemical oxygen demand (BOD) *(p. 416)* The amount of oxygen required by aquatic bacteria to decompose a given load of organic waste; a measure of water pollution.

Break-of-bulk point *(p. 395)* A location where transfer is possible from one mode of transportation to another.

Bulk-gaining industry *(p. 390)* An industry in which the final product weighs more or comprises a greater volume than the inputs.

Bulk-reducing industry *(p. 389)* An industry in which the final product weighs less or comprises a lower volume than the inputs.

Chlorofluorocarbon (CFC) *(p. 414)* A gas used as a solvent, a propellant in aerosols, a refrigerant, and in plastic foams and fire extinguishers.

Consumptive water usage *(p. 416)* The use of water that evaporates rather than being returned to nature as a liquid.

Cottage industry *(p. 384)* Manufacturing based in homes rather than in factories, most common prior to the Industrial Revolution.

Fission *(p. 408)* The splitting of an atomic nucleus to release energy.

Fordist production *(p. 424)* A form of mass production in which each worker is assigned one specific task to perform repeatedly.

Fossil fuel *(p. 385)* An energy source formed from the residue of plants and animals buried millions of years ago.

Fusion *(p. 409)* Creation of energy by joining the nuclei of two hydrogen atoms to form helium.

Geothermal energy *(p. 411)* Energy from steam or hot water produced from hot or molten underground rocks.

Greenhouse effect *(p. 414)* The anticipated increase in Earth's temperature caused by carbon dioxide (emitted by burning fossil fuels) trapping some of the radiation emitted by the surface.

Just-in-time delivery *(p. 395)* Shipment of parts and materials to arrive at a factory moments before they are needed.

Labor-intensive industry *(p. 396)* An industry for which labor costs comprise a high percentage of total expenses.

Maquiladora *(p. 421)* A factory built by a U.S. company in Mexico near the U.S. border, to take advantage of the much lower labor costs in Mexico.

New international division of labor *(p. 420)* Transfer of some types of jobs, especially those requiring low-paid, less-skilled workers, from more developed to less developed countries.

Nonconsumptive water usage *(p. 416)* The use of water that is returned to nature as a liquid.

Nonpoint source pollution *(p. 417)* Pollution that originates from a large, diffuse area.

Nonrenewable energy *(p. 410)* A source of energy that has a finite supply capable of being exhausted.

Outsourcing *(p. 420)* A decision by a corporation to turn over much of the responsibility for production to independent suppliers.

Ozone *(p. 414)* A gas that absorbs ultraviolet solar radiation and is found in the stratosphere, a zone 15 to 50 kilometers (9 to 30 miles) above Earth's surface.

Passive solar energy systems *(p. 412)* Solar energy systems that collect energy without the use of mechanical devices.

Photochemical smog *(p. 415)* An atmospheric condition formed through a combination of weather conditions and pollution, especially from motor vehicle emissions.

Point source pollution *(p. 417)* Pollution that enters a body of water from a specific source.

Pollution *(p. 414)* Concentration of waste added to air, water, or land at a greater level than occurs in average air, water, or land.

Post-Fordist production *(p. 424)* Adoption by companies of flexible work rules, such as the allocation of workers to teams that perform a variety of tasks.

Potential reserve *(p. 404)* The amount of a resource in deposits not yet identified but thought to exist.

Proven reserve *(p. 404)* The amount of a resource remaining in discovered deposits.

Recycling *(p. 426)* The separation, collection, processing, marketing, and reuse of unwanted material.

Remanufacturing *(p. 426)* The rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts.

Renewable energy *(p. 410)* A resource that has a theoretically unlimited supply and is not depleted when used by people.

Right-to-work law *(p. 422)* A U.S. law that prevents a union and a company from negotiating a contract that requires workers to join the union as a condition of employment.

Sanitary landfill *(p. 418)* A place to deposit solid waste, where a layer of earth is bulldozed over garbage each day to reduce emissions of gases and odors from the decaying trash, to minimize fires, and to discourage vermin.

Site factors *(p. 388)* Location factors related to the costs of factors of production inside a plant, such as land, labor, and capital.

Situation factors *(p. 388)* Location factors related to the transportation of materials into and from a factory.

Vertical integration *(p. 420)* An approach typical of traditional mass production in which a company controls all phases of a highly complex production process.

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Human Impacts on Water Resources

Humans use water for many purposes, including manufacturing, agriculture, and recreation, as well as direct consumption. Access to fresh clean water is not possible for many people in the world. The poor condition of infrastructure restricts access to fresh clean water for some people. Other people live in arid locations.

1. What are the principal uses of water resources other than direct consumption by people and animals?
2. Given that the world's total supply of water is constant, how might we increase the world's supply of water suitable as a resource for use by people?
3. What steps, if any, are being taken in your school or community to conserve water?

EXPLORE

An Early Industrial Town

Saltaire is a village in the United Kingdom built in the early years of the Industrial Revolution by Sir Titus Salt. Surrounding his factory, Salt built houses for the workers.

Fly to *Saltaire*.

Zoom in to eye alt around 3,500 ft. Salt's original factory is the large building immediately north of the balloon.

Click *More*, then turn on *Transportation* layer. The factory was built before the invention of cars and trucks.

1. What two modes of transportation from the nineteenth century (still visible immediately to the north and south of the factory) would have been used to move materials and products?

   Turn on *Photos*. Move the cursor over one of the photos on top of the factory.
2. What was Salt's factory used for? (Hint: Turn on *Gallery* in the *Primary Database* and click on the "i" (for information) icon near the north side of the factory.)

   Drag *street view* to the southwest side of the factory complex.
3. Why might the structure no longer be suitable for manufacturing?

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