**Chapter 11: Industry & Energy**

**Key Issue 1: Where Is Industry Distributed?**

**Introducing Industry and Energy** The hearth of modern industry – meaning the manufacturing of goods in a factory – was in northern England and southern England during the second half of the eighteenth century. From these two locations, industry diffused to Europe and to North America in the nineteenth century and to other regions in the twentieth century.

**Industrial Revolution** The Industrial Revolutionwas a series of improvements in industrial technology that transformed the process of manufacturing goods. Prior to the Industrial Revolution, 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.

Several inventions transformed the way in which goods were manufactured, beginning with the steam engine. The revolution in industrial technology created an unprecedented expansion in productivity, resulting in substantially higher standards of living. The Industrial Revolution resulted in new social, economic, and political inventions, not just traditional ones. The changes involved a gradual diffusion of new ideas and techniques over decades rather than an instantaneous revolution. Among the first industries impacted by the Industrial Revolution were iron, transportation, textiles, chemicals, and food processing.

**Fossil Fuels** Historically, people relied primarily on power supplied by themselves or by animals, known as **animate power**.Supplementing animal power was energy flowing from water and burning **biomass fuel**, which is fuel derived from plant material and animal waste. Biomass remains an important sources of fuel in some developing countries, by 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 fossil fuels that are used today. Five-sixths of the world’s energy needs are supplied by three fossil fuels: coal, petroleum, and natural gas.

**Industrial Regions** Industry is concentrated in Europe, North America, and East Asia. European industrial areas tend to be located in regions with abundant energy, raw materials such as iron ore, and labor concentrations. North American industrial areas are located in a band from the Great Lakes to the East Coast and the California Coast. East Asia’s industrial areas are in China along the coast and in Japan.

**Key Issue 2: Why Are Situation and Site Factors Important?**

Geographers try to explain why one location may be more profitable for a factory than others. A company typically faces two costs centered around geography:

* **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 labor, capital, and land.

**Situation Factors: Proximity to Inputs** Manufacturers purchase 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 a product is transported, the higher the cost, so a manufacturer tries to locate its factory as close as possible to its inputs and markets. 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. 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 particularly important inputs for many industries. Minerals are either nonmetallic or metallic. In weight, more than 90 percent of minerals that humans use are nonmetallic. Building stones, gemstones, and fertilizers are examples of nonmetallic minerals that humans commonly use. Metallic minerals have properties that are especially valuable for fashioning machinery, vehicles, and other essential elements of contemporary society. Many metals are capable of combining with other metals to form alloys with distinctive properties important for industry. A ferrous alloy contains iron and a nonferrous one does not. Iron is extracted from iron ore, by far the world’s most widely used ore. Important metals used to make ferrous alloys include chromium, manganese, molybdenum, nickel, tin, titanium, and tungsten. Important metals used to manufacture products that don’t contain iron and steel include aluminum, copper, lead, lithium, magnesium, zinc, precious metals, and rare earth metals.

**Proximity to Inputs: Copper Industry** Copper production involves several steps. Mining copper ore is a **bulk-reducing industry** because the heavy, bulky ore that is extracted from the mines is mostly waste. The second step in copper production is the concentration mills that grind the ore into fine particles that produce copper. Copper smelters then remove more impurities. 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. Copper that is ready for use in other products is produced in foundries. As a bulk reducing industry, copper concentration mills and smelters are built near the mines to minimize transportation costs. Since so much waste has already been disposed of, proximity to the mines is a less critical factor in determining the location of the foundries.

**Situation Factors: Proximity to 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. For example, steelmakers have traditionally located near raw materials; steel fabricators have traditionally located near the markets. Beverage bottlers also locate near large markets to cut down on the cost of shipping.

**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 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 makers of parts for motor vehicles are another example of specialized manufacturers with only one or two customers.

**Perishable-Products Companies** To deliver their products to consumers as rapidly as possible, perishable-product 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. The daily newspaper is an example of a product other than food that is highly perishable because it contains dated information. Newspaper publishers must locate near the markets to minimize transportation costs. People demand their newspaper as soon after it’s printing as possible.

**Motor Vehicle Production and Sales** The motor vehicle is a noted example of a fabricated metal product that is likely to be built near its market. Around 90 million new vehicles are sold every year worldwide. China accounts for 27 percent of those sales, other Asian countries 22 percent, North America 23 percent, and Europe 17 percent. China and the rest of Asia each have 26 percent of world production, and Europe and North America each have 19 percent. Most of the vehicles that are produced in these regions are sold in their respective markets.

**Changing Situation Factors: Steel** The two principal inputs in steel production are iron ore and coal. The majority of 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** 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. The increasing importance of proximity to markets is demonstrated by the recent growth of steel minimills. Rather than iron ore and coal, the main input into minimill production is scrap metal. Minimills are less expensive to operate then traditional steel mills and they can locate near their markets because their main input—scrap metal—is widely available. World steel production is declining in developed countries and increasing in developing countries. Overall world steel production doubled between 1980 and 2013, with the biggest increase in production taking place in China.

**Truck, Train, Ship, or Plane?** Inputs and products are transported in one of four ways: via ship, rail, truck, or air. Shipping costs are variable depending on the mode of transport used. The farther a product is transported, the lower the cost per unit distance. Longer-distance transportation is cheaper per unit distance 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 variable rates for each of the four modes because of the loading and unloading expenses differ for each mode:

* Trucks are primarily used for short-distance delivery because they can be loaded and unloaded quickly and at low costs.
* 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.
* 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.
* Airplanes are most expensive for all distances, and are usually reserved for expedited delivery of small-bulk, high-value packages.

**Break-of-Bulk Points** Mixed modes of transportation are often used. Industries which use a number of different shipping modes tend to locate at **break-of-bulk points**,which is a location where transfer among transportation modes is possible. Important break-of-bulk points include seaports and airports. 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 into trucks at the other end. Large ships have been specially built to accommodate large numbers of rectangular boxlike containers. Regardless of transportation mode, costs increase 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.

**Just-in-Time Delivery** Proximity to market has become more relevant in recent years due to the emergence of just-in-time delivery. **Just-in-time delivery** is the shipment of parts and materials to arrive at a factory moments before they are needed in the production process. 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. Just-in-time delivery minimizes the costs a manufacturer incurs in wasteful inventory, and in storage space. However, natural disasters, traffic, and labor unrest can disrupt just-in-time delivery systems.

**Site Factors in Industry** Site factors are industrial location factors related to the costs of factors of production inside a plant. For some companies, site factors are more important than situation factors in deciding the location of a plant. Labor, capital, and land are three production factors that vary among locations.

**Labor** Minimizing labor costs is important for some industries and the variation of labor costs around the world is large. A **labor-intensive industry** is an industry in which wages and other compensation paid to employees constitutes a high percentage of expenses. The reverse case, an industry with a much lower-than-average percentage of expenditures on labor, is considered capital intensive. 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. 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.

**Capital** 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. 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. The ability to borrow money has become a critical factor in the distribution of industry in developing countries.

**Land** Contemporary factories operate most efficiently when laid out in one-story buildings. Raw materials are typically delivered at one end and moved through the factory in conveyors or forklift trucks. The land needed to build one-story factories is now more likely to be available in suburban and rural locations. With trucks now responsible for transporting most inputs and products, proximity to major highways is important for factories. Especially attractive is the proximity to the junction of a long-distance route and the beltway, or ring road that encircles most cities.

**Changing Site Factors: Clothing** Production of textiles (woven fabrics) and apparel (clothing) is a prominent example of an industry that generally requires less-skilled, low-cost workers. Textile and apparel production involves three principal steps: spinning of fibers to make yarn; weaving or knitting of yarn into fabric; and assembly of fabric into products. Spinning, weaving, and sewing are all labor intensive compared to other industries, but the importance of labor varies somewhat among them. Textile and apparel production involves three principle steps: spinning, weaving, and assembly.

**Spinning** Fibers can be spun from natural or synthetic elements. The primary natural fiber is cotton, and synthetics now account for three-quarters of world thread production. Because it is a labor-intensive industry, spinning is done primarily in low-wage countries. China produces one-quarter 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 place 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. For mechanized weaving, labor makes up a high percentage of the total production cost. As a result, weaving is primarily found on low-wage countries.

**Assembly** Sewing by hand is a human activity with a past that stretches back tens of thousands of years. 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.

**Key Issue 3: Why Do Industries Face Resource Challenges?**

Two issues are at the forefront for geographers when considering resources:

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

**Energy Supply** Earth’s energy resources are not distributed evenly. Coal is formed in lush, swampy tropical areas rich in plants. Thanks to the slow movement of Earth’s drifting continents, the tropical swamps of 250 million years ago have relocated to the mid-latitudes. Petroleum and natural gas formed millions of years ago from residue deposited on the seafloor. Some still lies beneath such seas as the Persian Gulf and North Sea, but other reserves are located beneath land that was underwater millions of years ago. The United States is highly dependent on all three fossil fuels.

**Demand for Energy** Industry relies on availability of abundant low-cost energy. Large quantities of energy are required to operate factories as well as to transport inputs into factories and products from factories to consumers. Energy is also required to produce food, keep homes comfortable, and transport people. Demand for energy comes from four primary types of consumption in the United States:

* Industries. Factories use approximately 40 percent natural gas and 30 percent each coal and petroleum.
* Transportation. Almost all transportation systems run on petroleum products.
* Homes. Natural gas and coal provide approximately equal shares of home needs.
* Commercial. Stores and offices have uses and sources similar to those of homes.

Developing countries comprised more energy usage than developed countries for the first time in 2006. China is currently the world’s leader in energy demand. The highest per capita consumption of energy remains in developed countries.

**Petroleum Challenges** Most of the world’s petroleum is produced in Southwest Asia and North Africa and Central Asia, regions where religious, ethnic, and political conflicts are common. Several developing countries possessing substantial petroleum reserves, principally in Southwest Asia and 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 resources. 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, world oil prices have increased sharply on several occasions, although gas prices are currently low in the United States, especially when adjusted for inflation.

**Fossil Fuel Reserves** 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:

* Coal. World reserves are approximately 1 trillion metric tons. 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.
* Natural Gas. World reserves are approximately 200 trillion cubic meters. At current demand, proven natural gas reserves would last 56 years. Less than 10 percent of proven reserves are in developed countries, primarily the United States.
* Petroleum. World reserves are approximately 1.6 trillion barrels. At current demand, proven petroleum reserves would last 55 years.

**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. Potential reserves can be converted to proven reserves from fields that have yet to be developed, or from fields yet to be discovered. Extraction from both types of fields is relatively (and possibly prohibitively) expensive.

**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 be profitable. Oil sands and hydraulic fracturing (commonly known as fracking) are two current examples.

**Petroleum Futures** Developed countries provide 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.

**World Oil Trade** The largest flows of oil are from Russia to Europe and from Southwest Asia to Europe and to Japan. The United States and Europe import more than half their petroleum, and Japan imports more than 90 percent. Canada and Saudi Arabia now supply much higher shares of petroleum to the United States than in the past. 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, principally by consuming more natural gas. Higher gas mileage standards have been enacted by regulatory bodies in many countries to help ease demand for petroleum. While the world will not totally deplete petroleum reserves in the twenty-first century, at some point extracting the remaining reserves will be so expensive and environmentally damaging that use of alternative energy sources will accelerate, and dependence on petroleum will diminish. In the future, all countries will need to pursue sustainable development strategies based on increased reliance on renewable energy sources.

**Nuclear Energy** While nuclear power is not renewable, some view it as an alternative to fossil fuels. The large amount of energy released from a small amount of material makes it an attractive alternative. One kilogram of enriched nuclear fuel contains more than 2 million time the energy in 1 kilogram of coal. Challenges are presented by nuclear power, though.

**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 employ nuclear power in some capacity, including 19 developed countries and only 11 developing countries.

**Potential Accidents** A nuclear power plant produces electricity from energy released by splitting uranium atoms in a controlled environment in a process known as **fission**. One product of all nuclear reactions is radioactive waste, certain types of which are lethal to people exposed to it. While nuclear power plants cannot explode, 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. The nuclear incidents in Chernobyl and Japan’s Fukushima Daiichi nuclear power plants are prominent examples of nuclear-related disasters.

**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.

**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 conflicts since because leaders realize that a full-scale nuclear war could terminate human civilization. The United States and Russia 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 is developing the capability.

**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 evenly around the world: Australia has 23 percent of the world’s proven uranium reserves, Kazakhstan 15 percent, and Russia 10 percent.

**High Cost** Nuclear power plants cost several billion dollars to build, primarily because of the elaborate safety measured 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. Mining uranium can pollute land and water and damage miners’ health. The complexities of secure transportation add to the cost. Consequently, generating electricity from nuclear plants is much more expensive than from coal-burning plants. 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 be generated on a sustained basis in a power-plant reactor with current technology.

**Energy Alternatives** 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 supply sources of renewable energy.

**Hydroelectric Power** Generating electricity from the movement of water is called hydroelectric power. 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 rely on hydroelectric power for most of their electricity.

**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 utilized 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. The prospects for increasing the use of biomass for fuel is limited, for several reasons:

* Burning biomass may be inefficient, as the energy required 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 compromised.

**Wind Power** Wind power has greater potential for increased use because only a fraction of the resource, wind, has been harnessed. Despite its perceived and actual benefits, wind power has been harnessed in only a few places. 90 percent of total world wind energy production is concentrated in China, North America, and Europe. A significant hurdle for developing countries in pursuing wind power is the high cost of wind turbine construction. Some critics oppose construction of wind turbines because they can be noisy, lethal for birds and bats, and may obscure the natural beauty of a landscape.

**Geothermal Energy** Energy from 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.

**Solar Energy** The ultimate renewable resource for sustainable development is solar energy supplied by the Sun. Solar energy provides the possibility for countries at low levels of development to promote sustainable development. Solar energy may serve as a way for developing countries to obtain electricity needed to operate businesses, schools, and hospitals. Solar sources currently supply only 1 percent of the electricity generated in the United States, although the potential for growth is limitless.

**Passive Solar Energy** Solar energy is harnessed through either passive or active methods. **Passive solar energy systems** capture energy without using special devices. These systems use south-facing windows and dark surfaces to heat and light building on sunny days. The Sun’s rays penetrate the windows and are converted to heat. Greenhouses are a prime example of the applications of passive solar energy.

**Active Solar Energy** **Active solar energy systems** collect solar energy and convert it either to heat energy or to electricity. The conversion can be accomplished either directly or indirectly. In direct electric conversion, solar radiation is captured with photovoltaic cells, which convert light energy to electrical energy. The photovoltaic cell was invented by Bell Laboratories in 1954. In indirect electric conversion, solar radiation is first converted to heat and then to electricity.

**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. There is little incentive for public and private utility companies to pursue solar technology, as coal remains cheap and significant investments in nuclear power have already been made. In developing countries, the largest and fastest-growing market for photovoltaic includes the 2 billion people who lack electricity, especially residents of remote villages. In order for countries to justify the expense of adopting solar powered electricity technologies, the cost of cells must drop and their efficiency must improve.

**Air Pollution** 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. Air pollution is a concentration of trace substances at a greater level than occurs in average air. These high concentrations of trace gases in the air can damage property and negatively affect the health of people, other animals, and vegetation. Most air pollution is caused by factories and power plants, in addition to motor vehicles. Factories and power plants produce sulfur dioxides and solid particulates, principally from burning coal. Carbon monoxide, hydrocarbons, and nitrogen oxides are released into the atmosphere when motor vehicles burn petroleum.

**Global-Scale Air Pollution** Geographers can examine air pollution at three scales: global, regional, and local. Climate change and ozone damage are both global-scale issues.

**Climate Change** Between 1880 and 2014, the average temperature of Earth’s surface increased by 0.89°C (1.6°F). An international team of U.N. scientists has concluded that this temperature increase is directly linked to human actions, particularly the burning of fossil fuels in factories and vehicles. Carbon dioxide is released into the atmosphere when fossil fuels are burned. According to U.N. scientists, the level of carbon dioxide in the atmosphere has increased by more than one-fourth during the past 200 years. A concentration of trace gasses in the atmosphere can block or delay the return of some of the heat leaving the surface heading for space, thereby raising Earth’s temperature. When fossil fuels are burned, one of the trace gasses, carbon dioxide, is discharged into the atmosphere. The anticipated 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.

**Ozone Damage** The stratosphere contains a concentration of **ozone** gas. The ozone layer absorbs dangerous ultraviolet rays from the Sun. Were it not for the ozone in the stratosphere, ultraviolet rays would damage plants, cause skin cancer, and disrupt food chains. Earth’s protective ozone layer is threatened by pollutants called **chlorofluorocarbons**.

**Regional-Scale Air Pollution** Air pollution may damage a region’s vegetation and water supply through acid deposition. **Acid deposition** is the accumulation of acids on Earth’s surface. Sulfur oxides and nitrogen oxides enter Earth’s atmosphere through the burning of fossil fuels, 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. 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. Geographers are particularly interested in the effects of acid precipitation because the worst damage is not experienced at the same location as the emission of the pollutants.

**Local-Scale Air Pollution** At the local scale,air pollution is especially severe in places where emission sources are concentrated, such as urban areas. Urban air pollution has three basic elements:

* 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.

**Water Pollution** Water pollution is a widespread problem 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 negatively affected other activities, but the volume of waste often exceeds the capacity that many rivers and lakes can accommodate.

**Demand for Water** Humans use approximately 3.6 trillion cubic meters (950 billion gallons) of water per year, or around 500 cubic meters (132,000) per capita. The most demand is for electricity, followed by agriculture and municipal sewage systems. 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.

**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 the fish die. Many factories and power plants use water for cooling and then discharge the warm water back into the river or lake. Fish adapted to cold water, such as salmon or trout, might not be able to survive the warmer water.

**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. Water-using manufacturers and municipal sewage are the two main point sources of water pollution.

**Nonpoint Source Pollution** Nonpoint sources usually pollute in greater quantities and are much harder to control than point sources of pollution. 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.

**Solid Waste Pollution** The average American generates about 2 kilograms (4 pounds) of solid waste per day. Residences generate around 60 percent of the solid waste, while businesses account for the remaining 40 percent. Paper products account for the largest share of solid waste in the United States, especially among residences and retailers. Manufacturers throw away large quantities of metals as well as paper.

**Sanitary Landfill** Using a **sanitary landfill** is by far the most common strategy for disposal of solid waste in the United States. Thousands of small-town “dumps” have been closed and replaced by a small number of large regional ones. Given the shortage of landfills, alternatives have been sought to dispose of solid waste. A rapidly growing alternative is incineration. Burning releases some toxins into the air and some toxins also remain in ash. Thus solving one pollution problem may increase another.

**Hazardous Waste** Disposing of hazardous waste is especially difficult. Hazardous waste includes heavy metals (including mercury, cadmium, and zinc), PCB oils from electrical equipment, cyanides, strong solvents, acids, and caustics. These may be unwanted by-products generated in manufacturing or waste to be discarded after usage. If poisonous industrial residuals are not carefully placed in protective containers, the chemicals may leach into the soil and contaminate groundwater or escape into the atmosphere.

**Key Issue 4: Why Are Industries Changing Locations?**

**Emerging Industrial Regions** In 1970, nearly one-half of world industry was in Europe and nearly one-third was in North America. Currently, these two regions constitute only one-quarter each of world industry. Industry’s share of total economic output has steadily declined in developed countries since the 1970s. 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 particularly aggressive in using low-cost labor in developing countries. To remain competitive in the global economy, they identify steps in their production processes that can be performed by low-paid, low-skilled workers in developing countries. The **new international division of labor** is the selective transfer of some jobs to developing countries. 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 led to intense scrutiny in the determination of optimal locations in the production process. 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.

**Mexico and NAFTA** The North American Free Trade Agreement (NAFTA), effective in 1994, eliminated barriers to moving goods among Mexico, Canada, and the United States. Because it is the nearest low-wage country to the United States, Mexico attracts labor-intensive industries that also need proximity to the U.S. market. Plants in Mexico near the U.S. border are known as **maquiladoras**, from the Spanish verb *maqullar*, which means “to receive payment for grinding or processing corn.” Under U.S. and Mexican laws, companies receive tax breaks if they ship materials from the United States, assemble the components at a maquiladora plant in Mexico, and export the finished product back to the United States.

**BRIC Countries** Much of the world’s future growth in manufacturing is expected to locate outside the principle industrial regions described earlier. The financial analysis firm Goldman Sachs coined the acronym BRIC to indicate the countries it expects to dominate global manufacturing during the twenty-first century: Brazil, Russia, India, and China. The four BRIC countries together currently control one-fourth of the world’s land area and contain 3 billion of the world’s 7 billion inhabitants. Their economies rank second (China), seventh (Brazil), ninth (Russia), and eleventh (India) in the world.

**Industrial Change in Developed Countries** In developed countries, 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 northeastern United States lost 3.7 million jobs in manufacturing in the same period. The South added 1.3 million manufacturing jobs, and the far western states gained 1.1 million. 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 Ozarks. 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 the North and forgo joining a union. Motor vehicle production is an example of an industry that has been attracted to the South on account of these factors. The principle lure for many manufacturers to locate in the South has been **right-to-work laws**. A right-to-work law requires a factory to maintain a so-called “open shop” and prohibits a “closed shop”. In a “closed shop” a company and union agree that everyone must join a union to work in the factory. The percentage of workers who are union members is much lower in the South than elsewhere in the United States. Twenty-five U.S. states 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. More importantly, the region has been especially attractive for companies working hard to keep out the unions altogether.

**Intraregional Shifts in Europe** Manufacturing has diffused from traditional industrial centers in northwestern Europe towards Southern and Eastern Europe. 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. These countries offer manufactures an attractive combination of two important site and situation factors: labor and market proximity. The workers offer manufacturers good value for money; they are less skilled but much cheaper than in Western Europe and they are more skilled than workers in Asia and Latin America. The region is also close to the wealthy markets of Western Europe.

**Skilled or 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.

**Skilled Labor** Two location factors influence industries to remain in these traditional regions: availability of skilled labor and rapid delivery to market.Traditionally, factories assigned each worker one specific task to perform repeatedly. Some geographers call this approach **Fordist** 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 contrasts with Fordist production. Four types of work rules distinguish post-Fordist lean production: teams, problem solving, leveling, and productivity.

**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.

**Recycling** Recycling has increased in the United States from 7 percent of all solid waste in 1970 to 34 percent in 2013. 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.

**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. 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.