RENEWABLE ENERGY

Learning Outcome 9.3.6

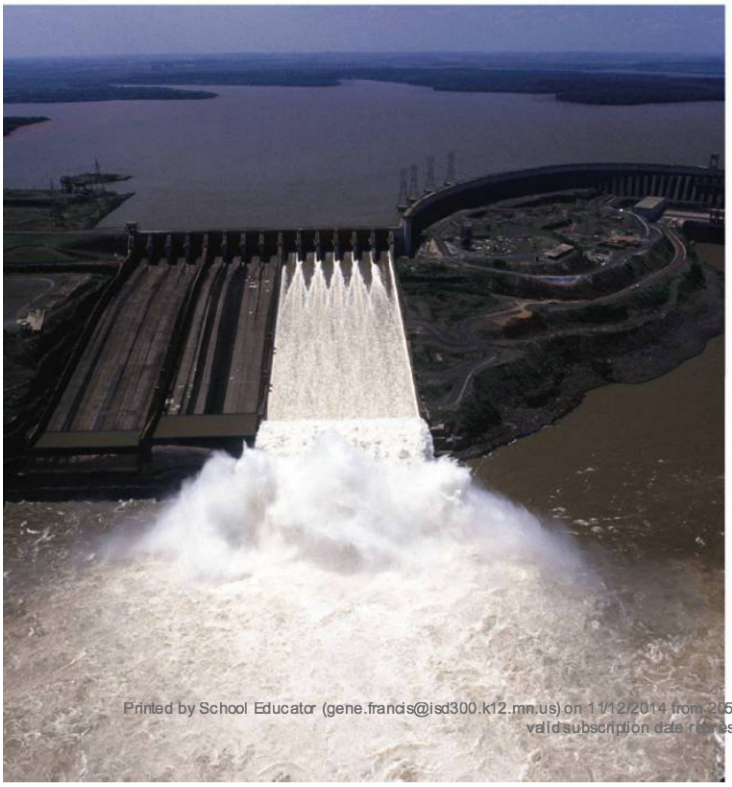
Identify challenges to increasing the use of alternative energy sources.

By a wide margin, hydroelectric power is currently the leading source of renewable energy for sustainable development in both developed and developing regions. Biomass and wind power have some usages, and geothermal and solar trail even further in current usage.

HYDROELECTRIC POWER. Generating electricity from the movement of water is called **hydroelectric power**. Water has been a source of mechanical power since before recorded history. It was used to turn water wheels, and the rotational motion was used to grind grain, saw timber, pump water, and operate machines. Hydroelectric is now the world's second-most-popular source of electricity, after coal. Worldwide generation of hydroelectric power is approximately 30 quad BTU, compared to 150 quad BTU for 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 9-44). The most populous country to depend primarily on hydroelectric power is Brazil. Overall, Brazil has made considerable progress towards sustainable development by generating approximately 85 percent of its electricity from renewable energy sources. Among developed countries, Canada gets two-thirds of its electricity from hydroelectric power; although the United States is the fourth-leading producer of hydroelectric power, it obtains only 8 percent of its electricity from that source. And this percentage may decline because few acceptable sites to build new dams remain.

▼ **FIGURE 9-44 ELECTRICITY FROM HYDROELECTRIC POWER** Hydroelectricity provides a large percentage of electricity in a number of developing countries, especially in Latin America and sub-Saharan Africa. The Itaipú hydroelectric dam is on the Paraná River in Brazil.



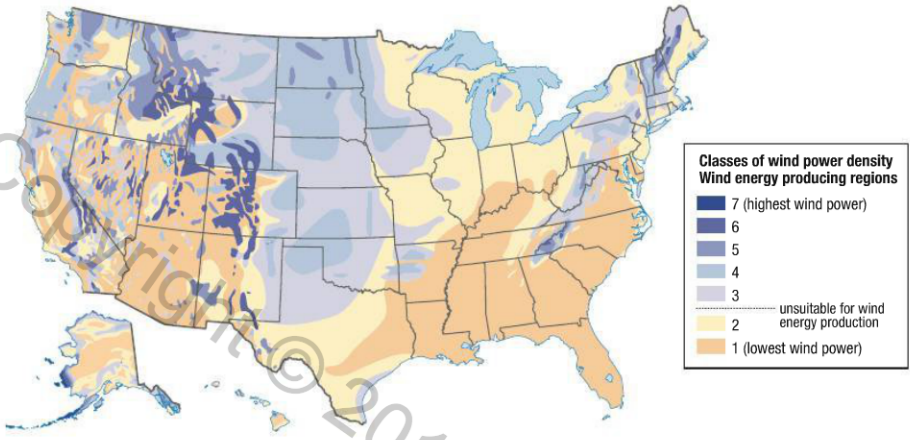
▲ **FIGURE 9-45 BIOMASS FUEL IN BRAZIL** Ethanol is produced from sugarcane in Brazil. This ethanol-producing plant is in Piracicaba.

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 in North America, Europe, and developing regions (Figure 9-45). Brazil in particular 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. Wind has also long been a source of energy, the most obvious examples of its uses being sailboats for travel and windmills for grinding grain. Like moving water turning a water wheel, moving air can turn a turbine.



◀ **FIGURE 9-46 WIND POWER** Winds are especially strong enough to support generation of power in the U.S. Plains states.

The benefits of wind-generated power seem irresistible. Construction of a windmill modifies the environment much less severely than construction of a dam across a river. And wind power has greater potential for increased use because only a small portion of the potential resource has been harnessed. However, wind power has divided the environmental community. Some oppose construction of windmills because they can be noisy and lethal for birds and bats. They can also constitute a visual blight when constructed on mountaintops or offshore in places of outstanding beauty.

Wind usage is similar to the pattern for biomass: Worldwide production is 3 quad BTUs, divided one-third each among North America, Europe, and developing regions. Hundreds of wind "farms" consisting of dozens of windmills each have been constructed across the United States; one-third of the country is considered windy enough to make wind power economically feasible (Figure 9-46), especially North Dakota, Texas, Kansas, South Dakota, and Montana. Twenty percent of Denmark's electricity is being generated through wind power. Wind power has been used only to a limited extent in developing countries. A significant obstacle is the cost of constructing the wind turbines.

Pause and Reflect 9.3.6

Chicago is nicknamed "the Windy City." Based on Figure 9-46, does the Chicago area appear to be a good location for wind power?

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, producing heated water or steam that can be tapped by wells. Energy from this hot water or steam is called **geothermal energy**.

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. Geothermal energy is being tapped in several locations, including California, Italy, New Zealand, and Japan, and other plate boundary sites are being explored. Iceland and Indonesia make extensive use of geothermal energy. Ironically, in Iceland, an island named for its glaciers, nearly all homes and businesses in the capital of Reykjavik are heated with geothermal steam (Figure 9-47). Worldwide production is less than 1 quad BTU, divided about evenly between developed and developing regions.

NUCLEAR FUSION. Some nuclear power issues could be addressed through nuclear **fusion**, which is the fusing of hydrogen atoms to form helium. Fusion releases spectacular amounts of energy: A gnat-sized amount of hydrogen releases the energy of thousands of tons of coal. But fusion can occur only at very high temperatures (millions of degrees). Such high temperatures have been briefly achieved in hydrogen bomb tests but not on a sustained basis in a power-plant reactor, given present technology. Sources such as fusion are not yet practical, so do not appear in statistics of current energy production.

▼ **FIGURE 9-47 GEOTHERMAL** Geothermal plant near Krafla, Iceland.

SOLAR ENERGY

Learning Outcome 9.3.7

Compare and contrast 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.

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. 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.

Pause and Reflect 9.3.7

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

GENERATING ELECTRICITY THROUGH SOLAR POWER. 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 9-48). 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

▲ **FIGURE 9-48 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 thought to have been crucified, buried, and resurrected (see Chapter 6).

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 9-49 SOLAR ENERGY IN DEVELOPING COUNTRIES** Solar panels are generating electricity for this family's house in Rumbek, South Sudan.

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 (Figure 9-49). 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.

CHECK-IN: KEY ISSUE 3

Why Are Energy Resources Important for Development?

- ✓ **Energy is supplied primarily by three fossil fuels: coal, petroleum, and natural gas.**
- ✓ **The three fossil fuels are nonrenewable, and production and reserves of these fuels are not distributed uniformly across Earth.**
- ✓ **Alternative energy sources include solar, nuclear, biomass, hydroelectric, geothermal, and fusion.**