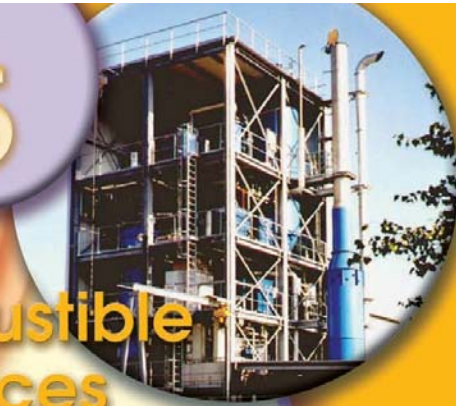
5

Renewable and Inexhaustible Energy Sources



Basic Concepts

- Identify the basic sources of renewable energy and inexhaustible energy.

Intermediate Concepts

- Describe at least three different methods of producing power from renewable energy resources.
- Provide at least six examples of different methods of producing power from inexhaustible energy resources.

Advanced Concepts

- Summarize several factors that influence the development of an energy resource.
- Explain advantages and disadvantages of various conventional and alternative energy resources.
- Discuss the environmental consequences most closely associated with the use of various conventional and alternative energy resources.

It is important to study energy in order to make the best use of our energy resources and to preserve them for future generations. Alternative energy resources are in various stages of utilization. Some, such as hydroelectricity, have been in use for years. In this sense, hydroelectricity is not really an alternative. Other energy resources, such as wind energy, are only now beginning to make a small contribution to the world energy mix. A few of the resources discussed are not used extensively at this time, but they may play a much greater role in the future.

Most energy has been stored in nature and can be traced back to the sun. For instance, the sun stores energy in plants and trees. This stored energy is released when plants or trees are burned. Plants and animals that have died millions of years ago also have stored energy. Today, we use this stored energy in the forms of coal, oil, and natural gas. These are just a few examples. Energy comes from many sources. These sources, as you learned in Chapter 2, have been divided into three categories:

- Nonrenewable energy sources.
- Renewable energy sources.
- Inexhaustible energy sources.

We will study energy resources in this chapter by classifying them as either renewable or inexhaustible. Nonrenewable energy sources were explained in Chapter 3.

Renewable Energy Sources

Renewable energy resources are those energy sources that can be replaced as needed on a relatively short-term basis. See **Figure 5-1.** This energy comes from plants and animals. Management of renewable energy sources is critical to their effective use. Once a tree is cut down, it is important to replant one to sustain this form of energy. The basic renewable energy sources include animals, food, wood, and alcohol, including methanol. See **Figure 5-2.** Energy can also be created from waste products, in a process called bioconversion.

Figure 5-1. This forest is an example of a renewable energy resource. Trees can be harvested, and new trees can be planted for future harvesting.

Animals

Animals were used as a main source of energy for work in this country into the 1900s. They are still used to produce power for farming in many third world nations and in certain cultures within the United States. Animals are capable of pulling heavy loads on sleds or wheeled vehicles that humans are not able to pull. See **Figure 5-3.** Animals served as a major source of mechanical power until the development of mechanical machines. In the United States and other developed nations, the development and refinement of the external and internal combustion engines slowly led to the replacement of using animals for work. Animals are also used for food.

Food

Food is another source of energy. Physical labor, exercise, and recreation all require energy. Energy from food also keeps our bodies warm. Our bodies use the energy from the food to produce heat, which keeps our bodies at the correct temperature. Food is a renewable source of energy because it can be regrown.

Figure 5-2. Basic renewable energy resources. A—Animals. (U.S. Department of Agriculture) B—Food. (U.S. Department of Agriculture) C—Wood. (U.S. Department of Agriculture) D—Alcohol. (DaimlerChrysler)

A B C D

Figure 5-3. Less than 100 years ago, animals were the energy source for most farmwork in the United States. In many countries, animal power is still widely used. This photo shows mules being used for plowing in the 1920s on a farm in the American Midwest. (U.S. Department of Agriculture)

Gasohol: An automobile fuel made from grains.

GREEN TECH
The practice of irresponsible forestry has irreversibly damaged some of our forests. Several organizations now exist to monitor and regulate every step of forestry in order to sustain forests.

The food supply continues to sustain us. Farmers plant and harvest their crops, including corn, soybeans, wheat, or other plant life. See **Figure 5-4.** Some foods not only supply humans with energy, but are also used to supply vehicles with energy. For example, ***gasohol*** is made from grains to fuel automobiles. It is described more extensively in the section on alcohol fuels. Food product waste can also be burned or converted into fuel. Successful experiments in producing fuels from gardening and agricultural wastes have been performed. They are described in the bioconversion section later in this chapter.

Wood

Wood is a very old source of energy. It has been used as an energy source since the prehistoric times, and it continues to be used as an energy source today. For many years, it has been used to heat homes and for cooking. By the early 1900s, the use of wood as a fuel declined. Other sources of energy that offered more energy per volume, such as oil and natural gas, were beginning to be used. Today, however, you can find wood-burning stoves and fireplaces in modern homes. See **Figure 5-5.** Wood pellet stoves are also a popular source of supplemental heat for some people. Once again, wood has become a useful source of energy.

When harvesting wood, the wood must be split; transported; dried for optimal efficiency; stacked; and manually loaded into a fireplace, stove, or furnace. Burning wood requires periodic stoking of the fire, and temperature control within the structure can be difficult to regulate. Depending on availability, wood can be an inexpensive energy source in comparison to other fuels. Denser woods, like oak and hickory, tend to yield a greater amount of energy per volume than many other species of wood.

Figure 5-4. The yearly cycle of planting, growing, and harvesting crops provides an abundant supply of food to serve as an energy source for people and animals. Some crops, such as these soybeans, can be used to produce other types of energy sources, such as biodiesel fuel for vehicles.

One major disadvantage of burning wood is that it produces great amounts of air pollution. Wood does not burn as cleanly or efficiently as other energy sources. The fact that it is burned by individual homeowners and not burned at a central location the way coal is burned at a power plant means it is less subject to environmental regulation. It is also less subject to pollution control devices. Woodstoves require periodic cleaning and disposal of ashes and are regarded as a more dangerous method of heating than other methods. Many residential fires occur each year as the result of woodstoves and fireplaces. ***Creosote*** is a tarlike substance that can build up on the walls of a chimney when wood is burned. Wood-burning stoves are particularly susceptible to creosote buildup. See **Figure 5-6.** On the positive side, wood is a renewable energy source that can be harvested regularly, if properly managed.

Figure 5-5. Modern wood-burning stoves have an efficient design that provides a pleasant, comfortable heating source. In certain situations, wood can be a less expensive heating source than other fuels.

Wood can also be converted to another hydrocarbon fuel. It can be changed into a liquid and used to fuel vehicles. One type of wood-based fuel that is being used is methanol fuel, which is further explained later in this chapter. If wood were to be used as a large-scale energy source, it is possible that the competition between using wood as an energy source and as a construction medium could increase. Large forests would need to be planted and maintained in order to have enough wood for all the uses.

Creosote: A tarlike substance that can build up on the walls of a chimney when wood is burned.

Alcohol

Alcohol is a liquid hydrocarbon that may be used as fuel. It is made from different crops, such as corn, sugar beets, and sugar cane. It can be used to power internal combustion engines, including those in

Figure 5-6. Since flammable creosote builds up in the chimneys of wood-burning stoves and fireplaces, periodic inspection and cleaning are important. Chimney sweeps do this work. The history of the chimney sweep traces back hundreds of years. This instructor at the Chimney Safety Institute of America (CSIA) annual Chimney Sweep School is explaining proper fireplace cleaning procedures. (CSIA)

Ethanol: Ethyl alcohol, sometimes referred to as grain alcohol.

Fermentation: The decomposition of carbohydrates found in plants with the production of carbon dioxide (CO_2) and acids.

Methanol: A clean-burning liquid used as fuel to power vehicles. It can be made from nonrenewable sources of energy, such as coal, or from renewable sources of energy, such as wood, plants, and manure. Methanol produces more energy than ethanol, per volume, and burns more slowly than gasoline.

Methyl alcohol: See *Methanol*.

Bioconversion: The process that produces energy from the waste products of our society.

Biomass: Waste products that can be used in bioconversion. Examples are organic material (such as trees, plants, grains, and algae) and wastes such as manure, garbage, sewage, and paper.

automobiles. In some foreign countries, such as Brazil, automobiles operate with 100% alcohol fuel. In the United States, we use a mixture of alcohol and gasoline, known as gasohol, to fuel some vehicles. Gasohol is a mixture of unleaded gasoline and ethyl alcohol, or ***ethanol***. Ethanol is sometimes referred to as grain alcohol. Gasohol does not, however, provide as much energy per volume as gasoline.

Ethanol

Ethanol is produced from biomass by the conversion process known as ***fermentation***, similar to the way alcohol made for consumption is produced. Fermentation involves the decomposition of carbohydrates found in plants with the production of carbon dioxide (CO_2) and acids. An ethanol plant is a plant where the crops are distilled and processed into alcohol for use as fuel. The alcohol is then often mixed with gasoline. Gasohol is used to power many automobiles today. It is a mixture of approximately 10% ethyl alcohol and 90% gasoline. Ethanol can be refined from cornstalks and other domestically grown plants.

Methanol

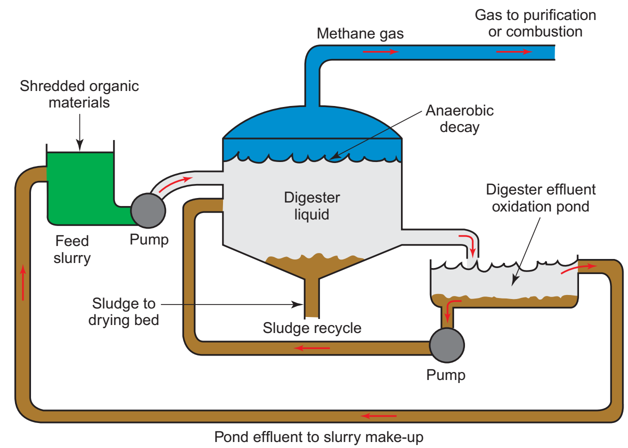
Methanol is a clean-burning liquid. It is also known as ***methyl alcohol***. Methanol can be made from nonrenewable sources of energy, such as coal, but it can also be made from renewable sources of energy known as biomass, such as wood, plants, and manure. It is used as a fuel to power vehicles. Methanol produces more energy per volume than ethanol. Therefore, it does not need to be mixed with gasoline to produce good power. Methanol also burns more slowly than gasoline. The redesign of engines specifically engineered to run on methanol has given methanol the ability to produce as much power as gasoline. Because methanol burns more slowly, it has smoother engine performance than gasoline. Methanol is being substituted for gasoline in some transportation systems, but a large infrastructure for the refinement and distribution of methanol is not yet in place in the United States. Furthermore, the amount of land that would have to be occupied to harvest plant products specifically for conversion to methanol would be tremendous, if the United States or any other country attempted to replace gasoline with methanol on a large-scale basis.

Bioconversion

The process that produces energy from the waste products of our society is known as ***bioconversion***. The waste is known as ***biomass***. Biomass is organic material, such as trees, plants, grains, and algae. Wastes, such as manure, garbage, sewage, and paper, are also sources of biomass. All these sources of biomass can go through a bioconversion. They can be burned or converted into alcohols, such as ethanol and methanol. Biomass conversion can also yield petroleum substitutes and methane gas.

A ***methane digester*** converts shredded organic materials into methane gas that can be used for heating, used for power generation, or purified and stored for distribution. See **Figure 5-7.** The type of bioconversion used by a methane digester is also known as ***anaerobic digestion***, or decay, which refers to decay without the use of oxygen. A less complex way of using biomass as an energy source is simply to burn the biomass.

Figure 5-7. A methane digester produces usable methane gas from decaying organic matter.



Methane digester: A vessel that converts shredded organic materials into methane gas, which can be used for heating, used for power generation, or purified and stored for distribution.

Anaerobic digestion: Decay without the use of oxygen.

Several municipalities throughout the United States now shred and burn waste. See **Figure 5-8.** The heat energy is then used to produce electricity or for industrial processes. This type of bioconversion also helps solve a growing societal problem. As landfills reach capacity, there is a growing concern of how to get rid of unwanted waste generated by society. These ***waste-to-energy plants*** have gained in popularity in recent years because they are economically viable.

Waste-to-energy plant: A plant that shreds and burns waste. The heat energy is then used to produce electricity or for industrial processes.

Inexhaustible Energy Sources

Inexhaustible energy sources are those sources of energy that will never run out. We are fortunate to have such energy sources, and it is in the best interest of our nation and the world to learn how to develop them for long-term use. The roots of most inexhaustible energy sources can be traced back to solar energy. It is solar energy that produces the changes in temperature that ultimately create tides and winds. The most frequently used of the inexhaustible energy sources is hydroelectricity, but others include geothermal energy, the wind, tides, Ocean Thermal Energy Conversion (OTEC), and hydrogen. Since forces beyond our control renew these sources, these sources are considered to be inexhaustible.

Hydroelectric Energy

Years ago, flowing water was used as a source of energy. See **Figure 5-9.** Waterwheels have few applications in contemporary America, but they were a major source of mechanical power for factories of colonial America. Water tapped from a nearby river is diverted into a sluiceway. A sluiceway is a channel that carries the water to a waterwheel. The force

GREEN TECH

A newer type of gasohol is called E85 and contains up to 85% ethanol. Flex-fuel vehicles can run on E85 the same way vehicles run on regular gasoline.

Figure 5-8. Municipal waste can be converted directly to energy by burning it. The heat energy can then be used for industrial processes or electrical generation. This waste-to-energy plant also recovers metals from the shredded waste before the burnable waste is sent to the furnace. (Union Electric Company)

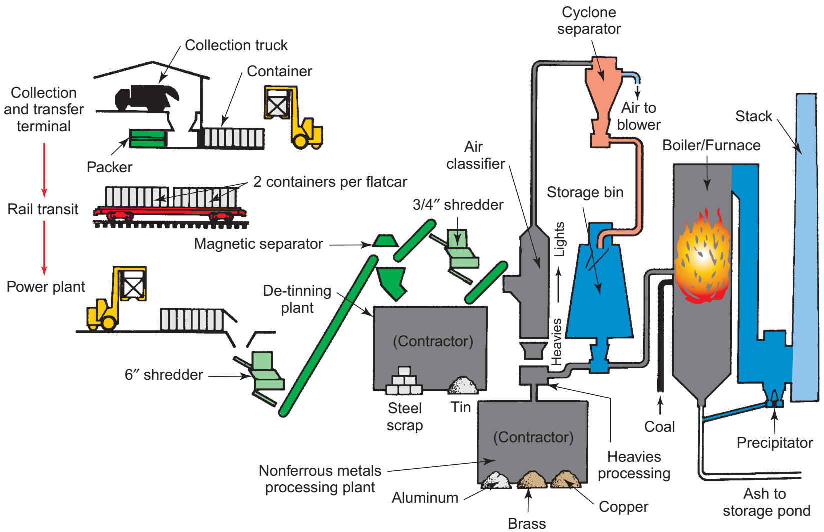


Figure 5-9. For thousands of years, waterwheels have been used to harness the energy of flowing water. This large wheel is part of a restored gristmill located alongside a creek. The wheel is more than 10′ in diameter.

Technology Link

Construction: Preventing Infiltration

Insulating products help seal a structure to prevent infiltration of cold air in the winter and hot air in the summer. Infiltration is discussed in terms of *air exchanges per hour*. One air exchange per hour is approximately equivalent to all the air within the heated or cooled structure escaping and being replaced by fresh air at the outside temperature. Most buildings experience one to three entire air exchanges per hour. By reducing the number of air exchanges per hour, infiltration products conserve energy and reduce the associated costs to the building owner. The following energy conservation products help to protect structures from heat loss or cool air loss by infiltration:

- *Caulk* is one of the most common and least expensive infiltration prevention products available. Silicone-based caulks tend to have exceptional adhesive properties to a variety of building materials, including wood, metal, and glass.
- *Expandable foam* is designed for gaps that are too large to seal effectively with caulk. Typical opportunities to use expandable foam often occur around the outsides of windows and door frames, as well as where the sill plate meets the foundation in older buildings. Manufacturers of expandable foam recommend practicing before using foam on a live application, as it continues to expand for a period of time after it has been applied to a gap. It is easier to trim dry foam with a utility knife than to try to manipulate the foam when it is wet.
- *Weather-tight doorstop molding* is similar to similar doorstop molding, but it has an additional foam rubber bead attached. Attach weather-tight molding so the foam bead is wedged snugly between the door and frame, creating a tight seal.
- *Weather-tight threshold* is used to replace older thresholds to prevent a gap underneath an exterior door.
- *Switch and receptacle sealers* are inexpensive and effective products for preventing infiltration. In a wall, junction boxes take up the space where insulation would normally be placed, so switch and receptacle sealers compensate for the lack of insulation and block the path for infiltration through the drywall opening.
- *Infiltration wraps* are a means of protecting exterior walls from infiltration during new construction. They are installed starting at one corner of the building and then literally wrapping the structure like a present. While doors and windows are cut out of the wrap, the rest of the walls have an extremely effective infiltration barrier.
- *Sill seal gaskets* are used during new construction, when they are applied to the top of the foundation, prior to erecting the exterior walls. When the walls are bolted to the foundation, the sill seal gasket is compressed between the concrete and the wall to tightly seal this notoriously leaky area.

of the water is used to spin the wheel, creating mechanical power. This mechanical power was often transferred into a factory by a shaft attached to the waterwheel. From there, it was connected to machinery, often by a leather belt. This allowed many machines, such as saws, mills, and lathes, to be powered at a time that predated the electric motors often used to power such machinery today. There were two primary types of waterwheels. See **Figure 5-10.**

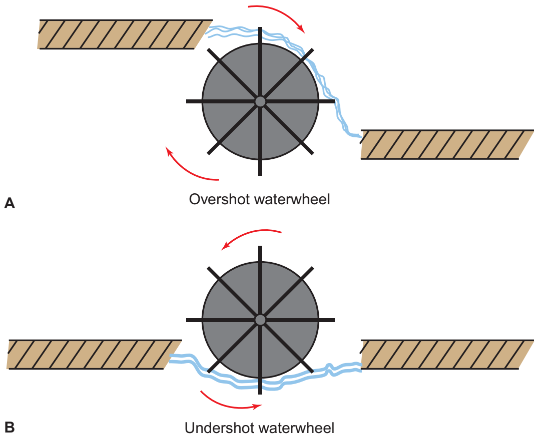
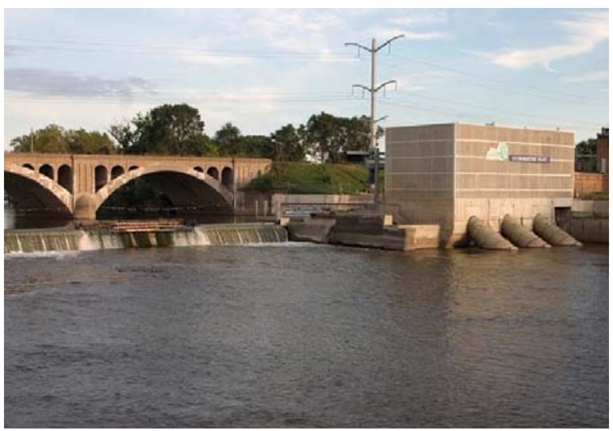


Figure 5-10. The two types of waterwheels. A—Overshot waterwheels are driven by water falling from above. B—Undershot wheels are driven from below.

Overshot waterwheel: A waterwheel that relies on an elevation change and makes use of the weight of the water, in addition to the water's force.

The ***overshot waterwheel*** relies on an elevation change and makes use of the weight of the water, in addition to the water's force. The ***undershot waterwheel*** does not require a significant elevation change and primarily makes use of the force of the flowing water. Although flowing waters do not power manufacturing plants anymore, flowing water is still a valuable source of energy. ***Hydroelectric energy*** is the use of flowing waters from waterfalls and dams to produce electricity. See **Figure 5-11.**

Figure 5-11. Hydroelectric power can be even generated by small rivers and low dams. This plant, operated by a small midwestern city, generates enough electricity to operate a sewage treatment facility serving several adjoining communities.



How a hydroelectric plant works

Hydroelectricity cannot really be considered an alternative form of energy because it produces a significant amount of U.S. energy. Dams are used to trap and store water. See **Figure 5-12.** A gate lets the water in. When the gate is open, the water rushes through a tunnel known as a ***penstock***. At the end of the penstock is a water turbine. The turbine turns as the water comes rushing in, causing the generator to spin. The mechanical energy that spins the generator is converted into electricity. The electricity is then sent off to power companies through electric lines and distributed to customers. This process is described in much greater detail in Chapter 8.

Undershot waterwheel: A waterwheel that does not require a significant elevation change and primarily makes use of the force of flowing water.

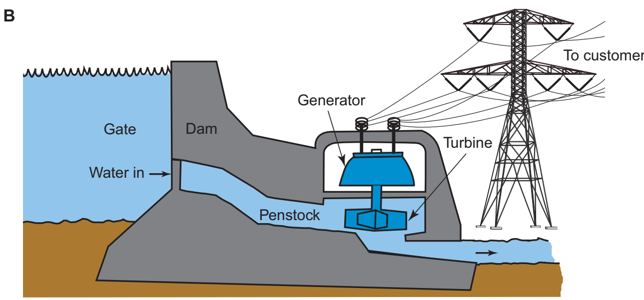
Hydroelectric energy: The use of flowing water from waterfalls and dams to produce electricity.

Penstock: A dam tunnel through which stored water rushes to a water turbine.

Figure 5-12. Hydroelectric power generation. A—Very large dams, such as the Hoover Dam in Nevada, impound huge amounts of water for use in electrical generation. (U.S. Department of Agriculture) B—This schematic shows how water stored behind a dam is used to drive turbines and electrical generators.

A

B



Curricular Connection

Language Arts: Hybrid Etymology

Language is always changing and evolving. In order to better understand where our words come from, it is useful to examine the word's etymology. *Etymology* is the study of a word's history by tracing its origin, the earliest known use, and analyzing the meaning of its components to create a definition. Often, the historic definitions of a word can be combined to form and explain its modern definition.

As we become increasingly aware of the for fuel-efficient vehicles, the word *hybrid* has entered into our everyday vocabulary. The engine on a hybrid vehicle is unique in that it pairs an internal combustion engine with one or more electric motors—it runs on both gas and electricity. This makes the vehicle more fuel efficient, making it better for the environment and your wallet. But where did the term "hybrid" come from? By examining its etymology, it becomes clear that the term was not chosen randomly to express this new technology.

The term hybrid is first thought to have been used around 1600. Sprung from the Latin word *hybridia*, it was used to describe the offspring of two genetically dissimilar parents. In this case, it specifically describes the baby of a female domestic pig and a male wild boar—much like a mule is the offspring of a female horse and a male donkey. Often, a hybrid is created through human intervention in breeding in an attempt to produce the best attributes of either parent in their young.

In that sense, hybrid vehicles have been created to capitalize on the best qualities of internal combustion engines and electrically powered vehicles. Running on gasoline, the hybrid vehicles can travel greater distances than a vehicle that is purely electric. Comparatively, the electric motor helps to reduce the amount of emissions created while also providing extra power. While an internal combustion engine and electric motor are two different technologies, they combine to create a hybrid that meshes their respective qualities into something new and different.

Hydroelectricity provides a vital percentage of electrical generating capacity in the United States. To date, almost all good opportunities for large-scale hydroelectric production have been developed, although Canada still has some excellent potential sites for future development. There is also considerable potential for the development of small-scale hydroelectric development in the United States. The generating capacity of most sites would, however, be quite limited.

The fact that hydroelectric plants can be taken off-line and brought on-line quickly is a great advantage. If the flow of the river is not strong, utilities will often let the water build up behind their hydroelectric dams all night long, to run generators only during the working day, when they are needed to meet maximum load capacity. This technique has proven so effective at meeting the peak load demand of some utilities that they have invested in hydroelectric power plants designed only to meet the peak demand. These peaking plants can actually consume more electricity than they generate, but they are still economical. Peaking plants pump water

uphill all night long, when there is excess power in the electrical grid produced by fossil fuel– and nuclear-powered generating facilities. The water is then allowed to flow back down through a penstock to spin a turbine generator. The reservoir may only be large enough to provide generating capacity for several hours per day. The plant may be brought on-line quickly, however, when power is needed to meet peak demands. Even though this type of plant operates at a net energy loss, it is relatively inexpensive to construct, compared to a base-load plant that produces power all the time. The fact that this type of plant allows for supplemental power when the utility needs it most makes it economical.

GREEN TECH

In addition to the damage to the rivers' ecological systems, the construction of dams also impacts surrounding land. Lower lands are used in the construction of dams, so any forests and life within those forests are affected.

Hydroelectricity and the environment

Hydroelectricity produces no fossil fuel pollutants, and the facilities are fairly quiet and perhaps less obtrusive than other generating plants. Hydroelectric power plants, however, are polluting. They just produce a different form of pollution by having the potential to alter the ecology of rivers.

If a river is dammed, migratory fish may not be able to return upstream to their spawning grounds. To counteract this problem, a series of ***fish lifts*** were installed in the Susquehanna River in Pennsylvania in the 1990s to help American shad return upstream. The fish lifts are in operation for only a two- to three-week period out of the year. They are like giant elevators that lift the fish and water up onto the top of the dam, where they dump into a sluiceway. The fish can then swim again until they reach the next dam, several miles upstream, where another fish lift has been installed. They instinctively swim toward a downstream current, which is artificially created during the times the fish lift is in operation. The fish lift is an example of the extent to which utilities may be required to accommodate nature in exchange for damming the river. The utilities may also be responsible for maintaining the river level at a safe depth for recreational boating and water sports. Draining the river too quickly could also create fish kills, as fish and other aquatic life become trapped in areas that could stagnate and evaporate if not replenished with flowing water.

Fish lift: A giant elevator-like device installed on dammed rivers to help fish return upstream during spawning season.

Tidal Energy

Tidal energy is another form of hydroelectric energy that offers tremendous generating potential if it can be harnessed. The gravitational pull of the moon and the rotation of the earth cause the changing tides. Significant tide changes occur about twice daily. There are only a few places in the United States where the tide change is so significant that it can be used to generate power.

How a tidal power plant works

The concept of a tidal power plant is simple. Make use of the flowing tide to spin a generator in one direction during the rush of high tide, and then spin the generator in the opposite direction with the exiting water during low tide. Of course, a natural bay that could be sealed by a permanent or floating dam known as a ***barrage*** is most ideal for using tidal power. See **Figure 5-13.** The extreme capital cost of tidal energy and the lack of ideal locations are the primary limitations to more extensive use of

Barrage: A permanent or floating dam that seals a natural bay in order to use tidal power.

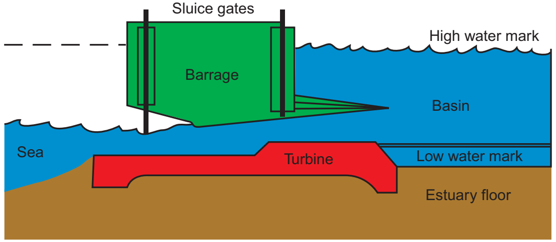


Figure 5-13. Tidal power can be generated by allowing the incoming tide to be impounded behind a dam (called a barrage). As the tide recedes on the seaward side of the barrage, the trapped water is allowed to flow out, rotating a turbine to generate electricity.

tidal energy. Factors in favor of using more tidal energy include that it is environmentally friendly, in comparison to other forms of power production, and the cost of maintenance and operation is low. The tidal energy is essentially free for the taking if it can be captured. Underwater ***tidal fences*** would have less impact on the environment, as they do not require flooding a basin to generate power.

Tidal fence: A barrier intended to prevent the power of tides from escaping back into the ocean.

Tidal energy and the environment

There is only one major environmental concern associated with tidal energy. It has to do with a possible ecological disturbance. The use of dams or barrages may create disturbances to the surrounding ecological environment.

Geothermal energy: Heat from the earth.

Mantle: Rock that conducts heat coming from the earth's core.

Magma: Molten rock located miles beneath the earth's surface.

Geothermal Energy

Geothermal energy is heat from the earth. *Geo* means "earth," and *thermal* relates to heat. The heat from the earth's core continuously flows outward. It is conducted by the surrounding rock known as ***mantle***. The mantle becomes molten and is then known as ***magma***. Magma is located miles beneath the earth's surface. Heat from magma is trapped underground. Sometimes, magma erupts from the earth in a volcano. Underground water turns to steam when it comes near this molten rock. Great amounts of steam are produced from the earth. The high pressure from the steam is used to turn turbines connected to generators. The generators then produce electricity. The production of electricity is the greatest use of geothermal energy. The United States leads the world in installed capacity of geothermal plants. Further development of geothermal energy for electrical generation is limited to locations where the heated steam is close enough to the earth's surface in order to make it economically recoverable.

Heat pump: An application of the use of geothermal energy for residential heating and cooling. A system of these pumps consists of pipes buried in the shallow ground and located near a home. Water flows through the pipes and conducts heat from the ground for transfer into the home.

How a geothermal heat pump works

Heat pumps are another application of the use of geothermal energy. They are used extensively for residential heating and cooling. The geothermal heat pump is based on the fact that ground temperature remains an approximate 55°F. A geothermal heat pump system includes pipes buried in the shallow ground and located near a home. Water flows through the pipes and conducts heat from the ground for transfer into the home. If the water enters the home at 55°F and that heat can be captured,

less conventional energy is needed to heat the home. See **Figure 5-14.** The energy from the earth reduces heating costs significantly, but the system has another big advantage over more conventional heating systems. It can be reversed and used to provide central air conditioning in the warm summer months.

Hydrogen sulfide gas: A gas that smells like rotten eggs, found within the steam of geothermal energy plants.

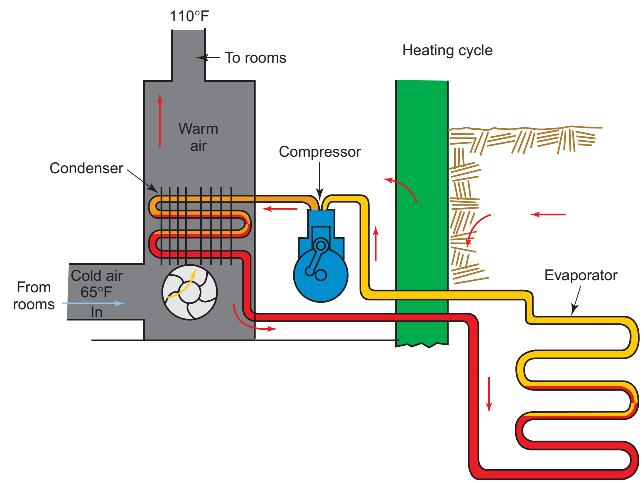
Geothermal energy and the environment

Geothermal energy plants have raised the ire of a number of environmental groups that regard them as unsightly, smelly, and extremely noisy. The ***hydrogen sulfide gases*** within the steam smell like rotten eggs, and the minerals commonly found in steam with little moisture have the capability of poisoning lakes and streams if they become airborne. The moisture from wet steam plants tends to be heavily laden with salt, which can create maintenance problems, due to buildup, and waste disposal problems, once the steam is brought aboveground. On a positive note, geothermal plants emit far less CO_2 into the environment than burning fossil fuels, and they make use of a heat source that is present for the taking.

Wind

For years, people built windmills in places where the wind blew much of the time. See **Figure 5-15.** The windmills pump water, grind grain, or do other useful tasks. Unfortunately, the wind has never been a totally

Figure 5-14. A geothermal heat pump has its evaporator coil buried in the ground. Refrigerant in the evaporator coil picks up heat from the ground (even in cold weather) and is carried inside, where it passes through a compressor. In the condenser coil, the heat is given up to the flow of indoor air, warming the indoor spaces.



Career Connection

Meteorologists

Science, Technology, Engineering & Mathematics

The function of meteorologists is to give accurate predictions of the weather. The aviation industry depends extensively on weather reporting. Air traffic controllers and pilots need to be kept aware of changing weather patterns for the safety of all passengers. Meteorologists' predictions are typically broadcast on television or radio stations for public use and interest. In order to provide up-to-date information, meteorologists analyze reports from specialized equipment. Using the technology of radio detecting and ranging (radar) and satellites, meteorologists can forecast both short- and long-term climate activity.

Knowledge of physics, geography, and math is essential for a meteorologist. Also important are communication skills, particularly the ability to speak clearly. Meteorologists frequently collect data useful in energy, power, and transportation. For instance, average wind speed charts can indicate which locations would be most favorable for a power company to consider using for wind power generation. Rain patterns can be used to help predict generating capacity for hydro plants, and accurate weather information is essential to most of the transportation industry. A bachelor's degree is required to be a worker in this field. The yearly salary may range from $35,000 to $73,000.

Figure 5-15. Windmills were fixtures on farms for many years, primarily providing energy to pump water. Much less efficient than today's wind generators, they were almost totally replaced by fossil fuel power sources during the second half of the twentieth century.

reliable energy source. Windmill usage decreased when fossil fuels that offered more convenience became available.

Today, the windmill is back in use, but it is mainly used to generate electricity. A way to harness this free energy produced by the wind is by a ***wind turbine***. Today, most windmills are referred to as wind turbines. A wind turbine has two different designs. See **Figure 5-16.** In both designs, the wind drives a propeller, or turbine, connected to a generator. The wind makes the turbine turn the generator, which produces electricity.

Proponents of wind as an energy source view it as an environmentally friendly alternative to fossil fuels. Generally, wind speeds in excess of 11 mph are necessary for any type of wind turbine connected to the power grid. Large-scale wind generators, such as those found on wind farms, require wind speeds of at least 13 mph, as determined by a ***wind velocity profile***, which characterizes the number of expected hours of a given wind speed for a particular location. This limits the potential for wind farming in some areas of the country, but wind energy is contributing to overall generating capacity of more than half the states in America. Other countries are tapping the potential of the wind at a faster growth rate than here in the United States.

Figure 5-16. Wind farms make use of many high-capacity wind turbines to generate significant amounts of electrical energy. (Shell Wind Energy)

Wind turbine: A propeller driven by the wind and connected to a generator. The wind makes it turn the generator, which produces electricity.

Wind velocity profile: Data characterizing the number of expected hours of a given wind speed for a particular location.

How a wind-turbine generator works

Regardless of design, all wind generators work essentially the same way. They all have some type of blades that capture the force of the wind. Unlike the windmills of previous eras, most modern wind generators are of a two- or three-blade design. See **Figure 5-17.** This is due to research that indicates multiple blades actually capture less wind than two- or three-bladed designs. The reason is that, every time a blade cuts through the air, it creates some turbulence or swirling air that opposes the penetration of the next blade. Wind turbines that have fewer blades actually allow the turbulence to stabilize before the next blade approaches.

GREEN TECH

Although energy is used to build wind turbines and install them in wind farms, the energy gained by using the turbines pays for the construction and installation in under a year on average.

Once the wind energy is converted to mechanical power by the blades, it is transferred to a gearbox for conditioning. The gearbox steps up the revolutions per minute (rpm) of the mechanical power and then transfers the power to spin the generator. The ***nacelle*** houses the gearbox, the generator, and a variety of equipment necessary to keep the wind turbine properly positioned into the wind and spinning at a safe speed. See **Figure 5-18.**

Nacelle: An enclosure that houses the gearbox, the generator, and a variety of equipment necessary to keep a wind turbine properly positioned into the wind and spinning at a safe speed.

When it comes to wind generation, increased wind speed is generally a good thing, but only to a point. A wind generator spinning at excessive speeds creates undue stress on the machine. Therefore, all wind generators must be created with a means of slowing themselves to prevent overspin. This can be done by feathering the pitch of the blades so they do not catch as much wind or by banking the wind turbine out of the wind to

Figure 5-17. Today's wind generators are usually designed with two or three blades for maximum efficiency. This small three-blade generator serves the needs of a single home, supplementing other energy sources.

create the same result. Frictional braking systems and systems that use a combination of means may also be used.

Wind and the environment

One obvious concern about increased wind generating capacity would be the amount of land that large wind farms would occupy. One recent study suggested that wind farms would need to occupy about 16,000 square miles to produce 20% of the electrical demand for the United States. Only a small percentage of this land would be physically occupied, however. About 95% of the land could serve dual use for farming or ranching, in addition to wind generation. Large wind turbines are also known to produce some noise pollution, which could be a detriment if located close to populated areas.

Hydrogen

To some, ***hydrogen*** is considered the ultimate energy source. This is because hydrogen is found in water, which covers about two-thirds of the earth's surface. It is also one of the most common elements in the galaxy. Therefore, hydrogen is considered inexhaustible. A problem is that hydrogen rarely exists in its pure form. Usually, it is locked in a compound. In the case of water, the two hydrogen atoms are bonded tightly with one atom of oxygen. See **Figure 5-19.**

Hydrogen: The first and simplest element on the periodic table. It is one of the most common elements in the galaxy.

Figure 5-18. The major parts of a horizontal wind turbine.

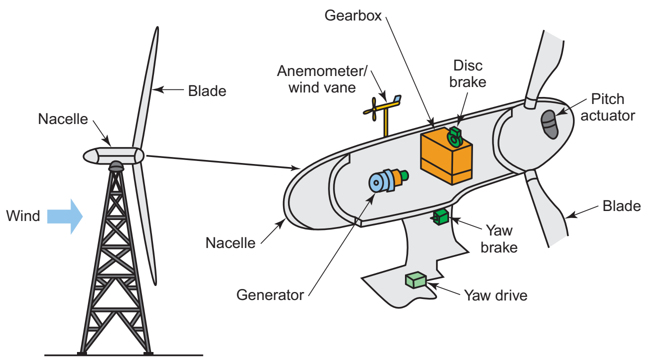
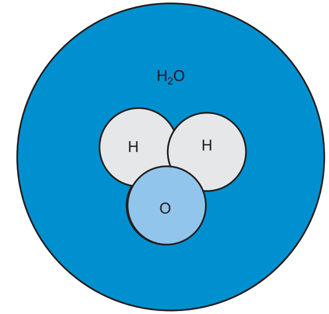


Figure 5-19. The water molecule consists of two atoms of hydrogen bonded to one atom of oxygen.



How hydrogen is collected

Breaking this bond and collecting the hydrogen can be done in several ways, all of which require energy in order to obtain another form of energy. So the question becomes, how much energy does it take to separate the hydrogen-oxygen bond? The answer has proven frustrating because the bond that holds water molecules together is very strong. Heating can break the bond, in a process called ***pyrolysis***. The use of an electrical current can also break the bond, in a process called ***electrolysis***. The bonds need to be broken in order for the hydrogen to be released and collected for use as an energy source. The pursuit of hydrogen as an energy source is worthy for several reasons. Hydrogen is a clean-burning combustible, so it could take the place of fossil fuels to power generators and automobiles. It is very plentiful, and techniques for safely storing hydrogen are improving. See **Figure 5-20.**

Pyrolysis: The process of separating the hydrogen-oxygen bond in water using heat.

Electrolysis: The process of separating the hydrogen-oxygen bond in water using an electrical current.

Hydrogen and the environment

The by-product of inefficient hydrogen combustion is water, about as environmentally friendly as it gets. Breaking the hydrogen-oxygen bond has proven so difficult, however, that more recent efforts to capture

Figure 5-20. Cars operating on hydrogen fuel cells have moved beyond the experimental phase and are being operated in small numbers in Germany, Japan, Singapore, and the United States. This is a demonstration vehicle based on a Mercedes-Benz automobile model. (DaimlerChrysler)

STEM Connection

Technology: Ocean Thermal Energy Conversion (OTEC)

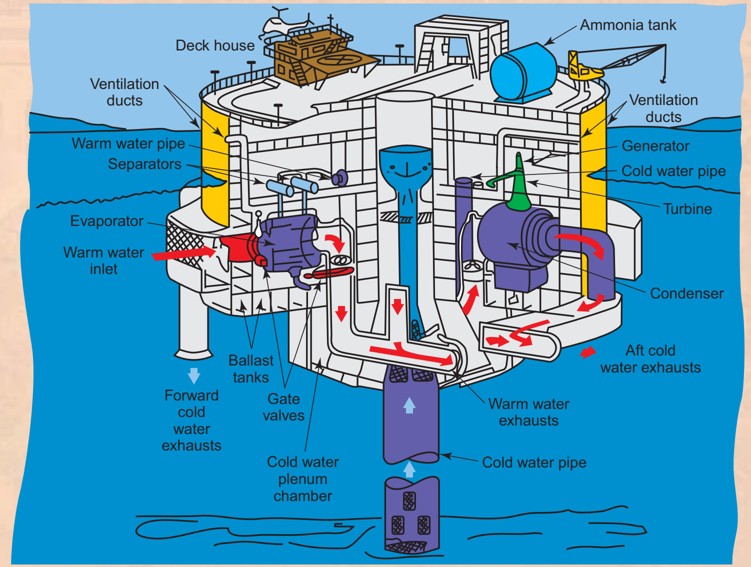
Any scuba diver knows that there are often vast differences between the temperature of surface waters and the temperature of waters some depth below. Imagine having the ability to take advantage of that temperature change and produce electricity! This is what Ocean Thermal Energy Conversion (OTEC) really does. See **Figure 5-A.**

The OTEC system of power generation relies on a refrigerant, such as ammonia, that vaporizes at a temperature less than the surface water temperature. The refrigerant also must recondense back into a liquid at a certain temperature, in accordance with the depth waters. The gas is locked in a closed loop. Warm surface waters are used to vaporize the refrigerant. The force of the expanding gas is used to spin a turbine coupled to a generator. Once the energy from the expanding gas has been transferred to the turbine, the gas is cooled back into a liquid using the temperature of the depth waters. The entire process requires about a 40°F temperature differential and goes on continuously to provide steady power generation. Obviously, this type of temperature differential is not available in all waters. OTEC is being tested domestically in Hawaii.

OTEC does not provide any fossil fuel pollutants. Small generating plants can run quietly and efficiently. They must, however, be located near land, in order to feed electricity onshore. Also, they must be tethered to the ocean floor, thereby creating a form of environmental and visual pollution. The changes in temperature created by OTEC generators can kill nearby marine life. Lastly, these generators appear to work best for small-scale power generation, leaving their ability to someday replace major power-producing sources in question.

hydrogen have used a process called steam reforming. This process involves vaporizing fossil fuels and mixing them with high-pressure, high-temperature steam. A nickel-based catalyst is introduced, and the process yields hydrogen. It also, however, yields carbon monoxide (CO) and CO_2, the primary greenhouse gas. Additionally, the source of the hydrogen yielded from this process is a nonrenewable form of energy. Scientists working with this process argue that it is worthy for two primary reasons. First, what has been learned about fossil fuels could soon be applied to other renewable hydrocarbon fuels, such as biomass. Second, the waste by-products, such as CO_2, are more easily controlled in a single large-scale production facility than they are coming out of automobile tailpipes. Therefore, converting car engines to run on only

Figure 5-A. A cutaway view of an Ocean Thermal Energy Conversion (OTEC) plant. The floating plant uses volatile fluids to generate electricity by taking advantage of the temperature difference between water at and below the surface. Such differences are most pronounced in tropical areas. (Lockheed Missiles and Space Company, Inc.)



hydrogen from fossil fuels could be much more environmentally friendly than burning the fossil fuels as they are currently burned. So, one plan could be to begin slowly converting over to a hydrogen-based economy. The first step would be to use fossil fuels for the production of hydrogen. We would then use a renewable source of energy, like biomass, to yield hydrogen. Ultimately, we would develop ways to cost-effectively yield hydrogen from water. Do not bet on this happening any time soon. Fossil fuels are still plentiful, and their associated environmental concerns have not yet gained enough prominence to influence society on a large-scale basis. Other nontechnical issues, such as tax credits, money allocated for research, and advantageous legislation, could help to spur the development of hydrogen as a major energy source for the future.

Summary

The origin of most forms of energy can be traced to the sun. Energy resources can come in many forms. Renewable energy sources are those sources that can be replaced. They mainly come from plants and animals. Inexhaustible energy sources are those sources of energy that will not run out. Some examples of these are the sun, the wind, geothermal energy, hydroelectric energy, and hydrogen. Virtually every energy source has some advantages and some disadvantages. Factors affecting the development of energy resources include technological factors, environmental factors, economic factors, and sometimes even political factors.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

anaerobic digestion
barrage
bioconversion
biomass
creosote
electrolysis
ethanol
fermentation
fish lift
gasohol
geothermal energy
heat pump
hydroelectric energy
hydrogen
hydrogen sulfide gas
magma
mantle
methane digester
methanol
methyl alcohol
nacelle
overshot waterwheel
penstock
pyrolysis
tidal fence
undershot waterwheel
waste-to-energy plant
wind turbine
wind velocity profile

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. The origins of most forms of energy can be traced to:
   A. the sun.
   B. gravity that creates pressure.
   C. heat from within the earth.
   D. water.
2. How are fossil fuels formed?
3. *True or False?* Food can be considered an energy source.
4. Describe several factors that can influence the development of a certain energy resource.

5. This fuel is a hydrocarbon fuel, but it is not a fossil fuel.
   A. Natural gas.
   B. Oil.
   C. Alcohol.
   D. Coal.
6. What is an advantage of using more alcohol in a gasoline mixture?
7. _____ and _____ are two types of alcohol fuels that could serve as substitutes for gasoline.
8. *True or False?* Biomass fuels can be made from industrial, societal, and agricultural waste.
9. _____ refers to the decomposition of material without the use of oxygen.
10. *True or False?* As a means of power generation and trash reduction, some municipalities have constructed waste-to-energy plants to burn garbage.
11. State the difference between renewable and inexhaustible energy sources.

For Questions 12 through 21, label each source of energy as nonrenewable (N), renewable (R), or inexhaustible (I).

12. Alcohol. _____
13. Animals. _____
14. Coal. _____
15. Hydrogen. _____
16. Natural gas. _____
17. Oil. _____
18. Sun. _____
19. Water. _____
20. Wind. _____
21. Wood. _____
22. *True or False?* Waterwheels once provided significant mechanical power for some industrial processes.
23. What is hydroelectric energy?
24. *True or False?* Large-scale hydroelectric power generation growth is predicted to increase in the next 25 years.
25. Hydroelectric dams do not produce fossil fuel pollutants. They are most closely associated with:
    A. noise pollution.
    B. low-level radioactive waste.
    C. water pollution.
    D. ecological damage.

26. The _____ provides one common use for residential heating with the use of geothermal energy.
27. *True or False?* Geothermal is an ideal energy source because it poses no environmental affects.
28. *True or False?* Hydrogen could be considered the ultimate energy source because it can be found in seawater.
29. _____ and _____ are two current methods of breaking the bond between hydrogen and oxygen in ordinary seawater.
30. _____ is a form of inexhaustible energy that makes use of the temperature difference between surface water temperatures and depth water temperatures.

STEM Activities

1. Design an experimental wind generator. Prepare drawings for building the experimental device and develop a bill of materials for construction. Construct the demonstration project. Test and refine the project.
2. Convert a small gas engine to run on an alternative fuel, like methanol or ethanol. This project will require research, testing, and modification.
3. Construct, test, and demonstrate a device that will change organic wastes into a usable energy form.
4. Tour a hydropower, waste-to-energy, or wind turbine generating facility.