- Wind is caused by pressure differences in the atmosphere and is also affected by specific conditions such as landmasses, temperature differences, cloud cover, and terrain.
- Wind resources can be shown on maps and calculated in detail for a specific site using computer programs that are checked against actual measurements.
- In the United States, major wind resources are concentrated on the coasts and the Midwest.
- Geothermal energy is available anywhere in the world; however, the best sites are near tectonic plate boundaries.
- In the United States, the western states have the best geothermal sites.
- Moving water has kinetic energy. The potential energy of reservoirs is changed to kinetic energy as the water falls out of reservoirs. Rivers and tides also have kinetic energy that can be exploited for power generation.
- Hydroelectric power is a renewable resource that provides clean energy but has negative impacts on fish and wildlife habitat, and it requires large areas of land for reservoirs. Many dams have positive impacts such as providing flood protection, irrigation water, and recreational opportunities.
- Biomass is currently the largest renewable resource in terms of energy obtained. As an energy source, biomass refers to any organic material used for a fuel.
- Ethanol is a renewable resource made primarily from corn; it has the ability to replace a portion of the gasoline required.
- Biofuel production has negative environmental impacts on land use, food and feedstock supplies, and water requirements.

KEY TERMS

biomass Organic material that is commonly used for fuels for heating, power generation, or making liquid fuels useful in transportation.

bitumen A black tarlike hydrocarbon classified as pitch; it can occur naturally or after refining petroleum.

breeder reactor A nuclear reactor designed to produce plutonium. It could extend uranium supplies considerably because it can convert the otherwise unusable ^{238}U into a fissionable fuel.

catagenesis The cracking process that results in the conversion of kerogens into hydrocarbons, including natural gas and oil.

diagenesis The process of converting constituents to a different product through application of heat and pressure.

diffuse horizontal irradiance (DHI) The portion of global horizontal irradiance that comes in indirectly (scattered radiation) from the sun.

direct normal irradiance (DNI) The portion of global horizontal irradiance that comes in a straight line from the sun.

ethanol The primary biofuel used as a gasoline additive; it is a type of alcohol.

fossil fuels Fuels that formed from decaying plant and animal matter and were primarily formed over millions of years. Fossil fuels include coal, oil (petroleum), and natural gas.

global horizontal irradiance (GHI) The total amount of shortwave radiation received on a horizontal surface.

hydrocarbon A molecule containing only hydrogen and carbon.

inverse square law A physics law that states that the flux from an isotropic point source is reduced by the square of the distance from the source to the receiver.

kerogen A mixture of organic chemicals that are part of the organic matter in sedimentary rocks.

pressurized water reactor (PWR) A nuclear reactor that includes fuel rods, control rods, and a moderator in a vessel that is filled with high-pressure water to prevent it from boiling. The water in the vessel serves as both a moderator and a means to move hot water to a heat exchanger and eventually a steam-driven turbine.

solar constant The power emitted by the sun that falls on 1 m^2. It is generally cited as 1,368 W/m^2.

Tokamak A fusion reactor used by researchers to investigate properties of plasmas; the goal is to create a fusion energy reactor that can be used for electrical power generation.

CHAPTER TRUE/FALSE QUIZ

Determine whether each statement is true or false. Answers are at the end of the chapter.

1. The most common use for coal is home heating.
2. A hydrocarbon molecule contains only hydrogen and carbon atoms.
3. When natural gas burns, carbon dioxide is released.
4. All reactors used for generating power are breeder reactors.
5. Delayed neutrons are not important for controlling reactors.
6. A Tokamak is a type of fusion reactor that attempts to confine the plasma.
7. The ozone in the upper atmosphere is particularly important because it absorbs infrared radiation.
8. The portion of global horizontal irradiance that comes in a straight line from the sun is called direct normal irradiance.
9. The solar constant is not affected by sunspots.
10. The prevailing wind direction in mid-latitudes is from east to west.
11. The wind resource in the United States is mainly in the eastern states.
12. *Transform plates* is the name given when two tectonic plates slide laterally past each other.

13. Low-quality heat from geothermal sources is not useful.
14. The largest installed electrical generating capacity for geothermal energy is in Iceland.
15. Iceland has a large geothermal resource because of its location at a boundary between tectonic plates.
16. Geothermal energy has no adverse environmental impacts.
17. Hydroelectric power is generated primarily by turbines turning a generator.
18. By definition, biomass consists of only nonorganic materials.
19. The primary crop used to produce ethanol is corn.
20. An advantage of burning biomass is that it does not produce air pollution.

CHAPTER MULTIPLE-CHOICE QUIZ

Complete each statement by selecting the one correct answer. Answers are at the end of the chapter.

1. All fossil fuels are composed of
   a. methane
   b. carbon dioxide
   c. sulfur
   d. hydrocarbons
2. Burning methane produces
   a. carbon dioxide and sulfur dioxide
   b. sulfur dioxide and water vapor
   c. carbon dioxide and water vapor
   d. none of these
3. A fossil fuel that releases carbon dioxide into the atmosphere when it is burned is
   a. coal
   b. petroleum
   c. natural gas
   d. all of these
4. A by-product of the fission process is
   a. hydrogen
   b. helium
   c. various radioactive fragments
   d. carbon dioxide
5. A serious environmental issue with nuclear reactors is
   a. radioactive waste
   b. carbon dioxide emission
   c. air pollution
   d. all of these
6. A Tokamak is a type of
   a. fusion reactor
   b. breeder reactor
   c. pressurized water reactor
   d. laser
7. Ozone in the stratosphere
   a. is considered to be a greenhouse gas
   b. absorbs greenhouse gases
   c. absorbs ultraviolet radiation
   d. contributes to global warming
8. Global horizontal irradiance is composed of
   a. direct normal irradiance and diffuse horizontal irradiance
   b. all irradiance received on a vertical surface
   c. ultraviolet irradiance and infrared irradiance
   d. visible light and infrared irradiance
9. The solar constant is known to vary slightly in response to
   a. wind conditions on earth
   b. sunspot activity
   c. cloud cover
   d. changes in stratospheric ozone
10. A common unit for expressing the solar constant is the
    a. W/m^2
    b. kWh/day
    c. W
    d. nm
11. Of the following forms of radiation, the one with the shortest wavelength is
    a. blue light
    b. red light
    c. infrared radiation
    d. ultraviolet radiation
12. The sun's output approximates a black body. This means that the sun
    a. has many absorption lines in its spectrum
    b. is nearly a perfect emitter of radiation at some temperature
    c. is hotter than most stars
    d. is approximately a point source of radiation
13. Two gases that absorb a large fraction of the infrared radiation from the sun are
    a. sulfur dioxide and water vapor
    b. ozone and carbon dioxide
    c. carbon dioxide and water vapor
    d. ozone and water vapor
14. For the past 200 years, carbon dioxide levels in the atmosphere have
    a. fallen
    b. stayed about the same
    c. risen
15. The winds in the mid-latitude cell are called
    a. easterlies
    b. westerlies
    c. northeast trade winds
    d. southeast trade winds
16. The strongest winds are, in general,
    a. at the poles
    b. at the equator
    c. in the desert
    d. in the jet stream
17. The doldrums exist
    a. near the poles
    b. at the equator
    c. around the Pacific rim
    d. in the jet stream

18. In the United States, high-grade geothermal resources are concentrated in the
    a. Pacific Northwest
    b. western states
    c. upper Midwest
    d. Southeast
19. The most important environmental effect of hydroelectric energy is
    a. the visual eyesore of dams
    b. the effect on fish and wildlife habitat
    c. noise
    d. air pollution
20. Ethanol is primarily used as a
    a. gasoline additive
    b. cattle feed
    c. fertilizer
    d. pesticide

CHAPTER QUESTIONS AND PROBLEMS

1. What are two products of burning fossil fuels?
2. What are diagenesis and catagenesis?
3. What is true about the mass of reactants and the mass of products in all chemical reactions such as combustion?
4. Why is water vapor considered to be a greenhouse gas?
5. What substance has the highest binding energy per nucleon?
6. What is deuterium and where is it found?
7. Why is a potential fusion reactor inherently safer than a fission reactor?
8. What is ITER and where will it be constructed?
9. What is the inertial fusion project?
10. How is the solar spectrum changed as it passes through the atmosphere?
11. Assume a 6-foot by 3-foot solar panel is oriented so that it has a maximum solar insolation of 1,000 W/m^2. What is the peak power delivered to the panel ~~(3.048 feet = 1 meter)~~?
12. What is the inverse square law in physics?
13. Show that the solar constant of 1,368 W/m^2 is equal to 32.8 $kWh/m^2/day$.
14. Compare the positive and negative environmental impacts of solar and wind energy.
15. What are geothermal heat pumps?
16. What is the purpose of a barrage dam?
17. What are two ways to obtain energy from tides?
18. Summarize the important benefits and negative impacts of large dams.
19. What are the positive and negative environmental impacts of using ethanol as a gasoline supplement?
20. In addition to ethanol, what are other uses for biofuels?

FOR DISCUSSION

What renewable resources are the best fit for the area you live in?

ANSWERS TO CHECKUPS

Section 1-1 Checkup

1. Fossil fuels formed from decaying plant and animal matter that was primarily formed over millions of years.
2. Methane is a primary constituent of natural gas; its chemical formula is CH_4.
3. The categories for coal are based on energy content and are anthracite, bituminous, sub-bituminous, and lignite.
4. Oil is used in the manufacture of lubricants, waxes, solvents, asphalt, hydraulic fluid, and vinyl.
5. Greenhouse gases are gases that contribute to global warming by absorbing short wavelength infrared energy and reradiating it at longer wavelengths.
6. Burning fossil fuels puts carbon dioxide, a greenhouse gas, in the air. Depending on the specific fuel, pollutants include sulfur, nitrous oxides, benzene, and others, which contribute to acid rain. Coal also produces a large amount of fly ash that creates a disposal problem. Other concerns include obtaining and transporting fossil fuels and safety issues.
7. Safety hazards exist for workers, particularly in the coal industry, and for the public in the form of air pollution. Transporting fuels can create hazards in the form of spills, such as the infamous oil spill by the *Exxon Valdez*.

Section 1-2 Checkup

1. A chain reaction is a self-sustaining reaction used in fission reactors to continue the process.
2. Normal uranium will not have a chain reaction. Enrichment separates useable ^{235}U, which can be used as a fuel from regular uranium.

3. Fuel rods are inserted along with control rods (good absorbers of neutrons). The control rods are moved out to increase the reaction or moved in to slow it. Hot pressurized water is converted to steam in a heat exchanger and drives a steam turbine and generator to make electricity.
4. A breeder reactor is a type of reactor designed to convert ^{238}U into ^{239}Pu, which is then used as a fuel.
5. Nuclear power produces almost no greenhouse gas emission or air pollution, and it is a more concentrated form of energy, so significantly less fuel is required than is the case with coal-fired plants. Its disadvantages include radioactive waste disposal and hot water releases to rivers and waterways. A reactor accident can have serious radioactive consequences and thus poses a safety issue.
6. One approach is the inertial fusion project, in which pellets of D-T fuel are dropped into a chamber and hit with high-power lasers, triggering the fusion reaction. The second approach is to keep a super-hot plasma of D-T fuel confined long enough to cause a reasonable fraction of the fuel to fuse.
7. The advantages of fusion reactors over fission reactors are that they produce significantly less radioactive waste and that no safety issues can result from losing control of the reactor.

Section 1-3 Checkup

1. The solar constant is the energy received on an area that is outside the atmosphere and oriented perpendicular to the sun's rays at the mean distance of the earth from the sun. Common units are W/m^2 and $kWh/m^2/day$.
2. The term *insolation* means incident solar radiation.
3. Carbon dioxide absorbs solar radiation and reemits it at longer wavelengths that do not escape the atmosphere as easily. As a result, more of the sun's energy is absorbed by the atmosphere.
4. Global horizontal irradiance is the total amount of shortwave radiation received on a horizontal surface.
5. Direct normal irradiance is the radiation that comes in a straight-line path from the sun; diffuse horizontal irradiance is scattered radiation and comes from all directions. DHI is not useful for solar concentrators.
6. The Maunder minimum is a period between 1645 and 1715 in which sunspot activity almost ceased, which led to much colder winters. Evidence from satellite measurements indicates that the solar constant is lower during periods of low solar activity.

Section 1-4 Checkup

1. The mid-latitudes are affected primarily by westerlies.
2. The doldrums are very calm winds near the equator. Ships required wind power to move, so sailors wanted to avoid these areas.
3. The air rises to the upper atmosphere, where it cools and becomes denser; hence it sinks.
4. The major wind resource areas in the United States are in the Midwest.
5. (1) Land use; (2) height, which creates aircraft hazards; (3) noise; (4) bird strikes; and (5) transmission line requirements crossing many miles of land.

Section 1-5 Checkup

1. High-grade geothermal sites have high underground temperatures within easy reach of drilling (less than 3 km) and have a large amount of stored geothermal energy. High-grade sites tend to be concentrated along geological plate boundaries and hot spots.
2. Geothermal power is good baseline power because it is a constant reliable source.
3. The western United States is closer to a tectonic plate, which provides a path for subterranean heat to escape.
4. Open-loop systems require a water source so that water can be injected into the ground. Closed-loop systems condense the steam and recycle it in the ground.

Section 1-6 Checkup

1. A barrage is a barrier such as a low dam that traps the inflow water of the tides.
2. Three methods for generating power from water are (1) storing runoff behind a dam and releasing it through a turbine, (2) using the moving water of a river (run of the river) to turn a turbine, (3) using tides by either trapping the inflow behind a barrier or turning a turbine in tidal current.
3. Negative environmental impacts include (1) loss of land for other purposes besides the reservoir; (2) silt loss downstream, which affects soil fertility; (3) water quality; and (4) fish blocking, kills, and loss of fish habitat.
4. Fish hatcheries, fish ladders, and screens around turbines.
5. SeaGen is a tidal current generator.

Section 1-7 Checkup

1. Biodiesel is made from vegetable oil, animal fat, or cooking grease that is combined with alcohol.
2. The upper Midwest, especially the Dakotas, Iowa, Illinois, and Indiana.
3. Some important issues for producing ethanol from corn include (1) diversion of corn from producing a feed and food crop; (2) reduced biodiversity because of single-crop farming; (3) more pesticide use; (4) increased water use because of the need for irrigation, production, and cooling; and (5) removal of wildlife habitats. A benefit is reducing dependence on oil and fossil fuels.
4. Municipal waste often includes nonorganic materials such as plastics, toxic metals, and similar materials that pollute the atmosphere.
5. Wood biofuels can help foresters manage forests by removing diseased and damaged trees, and help remove excess fuels for forest fires.

ANSWERS TO TRUE/FALSE QUIZ

1. F **2.** T **3.** T **4.** F **5.** F **6.** T **7.** F **8.** T **9.** F **10.** F **11.** F **12.** T **13.** F **14.** F **15.** T **16.** F **17.** T **18.** F **19.** T **20.** F

ANSWERS TO MULTIPLE-CHOICE QUESTIONS

1. d **2.** c **3.** d **4.** c **5.** a **6.** a **7.** c **8.** a **9.** b **10.** a **11.** d **12.** b **13.** c **14.** c **15.** b **16.** d **17.** b **18.** b **19.** b **20.** a