CHAPTER 17

Alternative and Renewable Energies

IN THIS CHAPTER

Summary: Global dependence on fossil fuels is resource limiting. Other non-polluting, renewable, and efficient sources of energy must be developed. Possible options include hydroelectric power, solar energy, hydrogen fuel cells, tidal, and biomass energy resources.

Keywords

KEY IDEA

✪ Clean fuels, ethanol, photovoltaic, semiconductor, Staebler-Wronski effect, distributed power, polycrystalline materials, electrochemical solar cells, geothermal, tidal energy

Clean Fuels

The most common fuels used for transportation in the United States are gasoline and diesel fuel, but there are several additional energy sources able to power motor vehicles. These include alcohols, electricity, natural gas, and propane. When vehicle fuels, because of physical or chemical properties, create less pollution than gasoline, they are known as *clean fuels.*

TIP

Clean energy is produced from renewable energy sources (e.g., solar, wind, biomass, hydroelectric, and geothermal). Figure 17.1 shows world energy use from various sources.

Electricity

Battery-powered or *hybrid gas-electric vehicles* are a great option for a lot of commuters. A hybrid vehicle, such as the Toyota Prius, has a 1.5-liter (L) gas engine that only kicks in when the car is accelerating or going uphill, or when the battery needs recharging. The Prius is

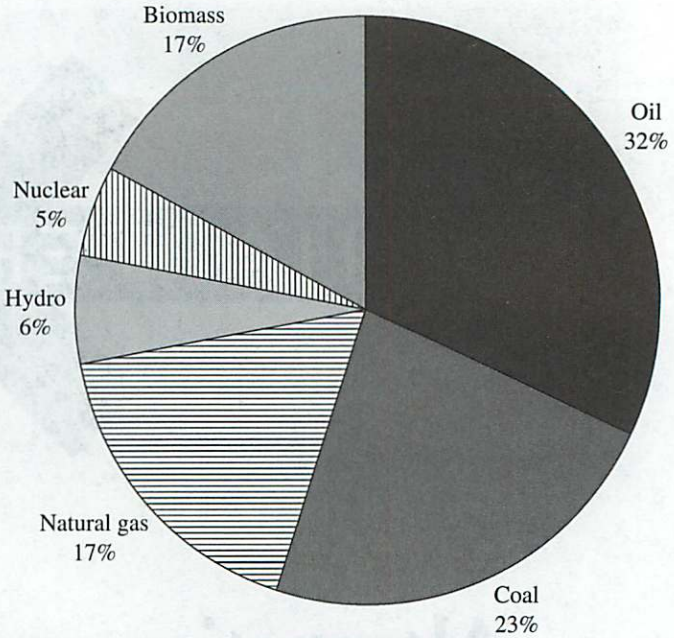


Figure 17.1 Over 70% of world energy choices originate from fossil fuels.

rated at 60 miles per gallon (mi/gal) (25 km/L) in city driving and 51 mi/gal (22 km/L) on the highway. Practically pollution free, it offers a great option for lowering vehicle emissions in polluted cities.

Low-power batteries limit electric cars' driving range, but this is improving. With batteries taking minutes instead of hours to recharge and running longer distances on one charge, electric power could become a widespread clean fuel for the future.

Biomass

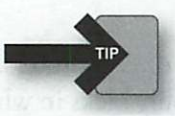
Plants use sunlight for energy. This energy is released as heat when plants (*biomass*) are burned. Forty percent of the world's population uses wood or charcoal as a main energy source, with the poorest countries (e.g., Ethiopia and Burundi) using biomass for 90% of their energy.

Biomass and *biofuels* are also produced from corn and other crops, as well as from wood or paper wastes. Since these renewable resources pull carbon dioxide out of the atmosphere as they grow, they decrease greenhouse gas buildup.

Ethanol

Ethanol (grain alcohol) is created by anaerobic digestion of high-sugar-content plants (e.g., grain and sugar cane). Ethanol-gasoline blends, known as *gasohol,* have been used in the United States and Brazil for many years. Pure ethanol gives great engine performance along with low hydrocarbon and toxic emissions.

Forty-two percent of the U.S. corn crop was used for ethanol fuel production in 2012. It is also added to gasoline to reduce incomplete combustion emissions. Ethanol is currently more expensive than gasoline, but as fossil fuels run out and new processing is developed, prices will improve.



The disadvantage of ethanol is its ability to augment the polluting effects of some compounds, like benzene. Ethanol acts as a solvent and slows the breakdown of benzene, toluene, and other chemicals in soil and groundwater. The longer these highly toxic compounds stay in the soil, the greater the public health risk.

Methanol

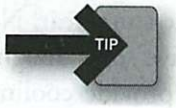
Methanol (wood alcohol), like ethanol, is a high-performance liquid fuel that releases low levels of toxic and ozone-forming compounds. It can be made for about the same cost as gasoline from natural gas, wood, and coal. All major auto manufacturers have produced cars that run on M85, a blend of 85% methanol and 15% gasoline. Cars burning pure methanol (M100) offer much greater air quality and efficiency advantages. Race cars use methanol because of its superior performance and fire safety characteristics.

Solar Energy

Sunlight is an immense source of natural energy. It lights and heats our planet and supplies energy for plant photosynthesis. The amount of solar energy reaching the Earth annually is much greater than worldwide energy demands, although it fluctuates with the time of day, location, and season.

Solar technologies use the sun's energy and light to provide heat, light, hot water, electricity, and cooling for homes, businesses, and industry. Accessibility to unblocked sunlight for use in both passive solar designs and active systems is protected by zoning laws and ordinances in many parts of the country.

Crystalline Silicon Solar Cells



Most solar power is based on the *photovoltaic* (PV) reaction, which produces voltage when exposed to radiant energy (especially light). A solar PV cell converts sunlight into electricity. Crystalline silicon is the light-absorbing semiconductor developed in the microelectronics industry and used in many solar cells.

Two types of crystalline silicon are used. The first, monocrystalline silicon, is produced by slicing thin wafers (up to 0.150 cm diameter and 350 microns thick) from a single, high-purity crystal. The second, multicrystalline silicon, is made by cutting a cast block of silicon into bars, and then wafers. It is the most common substrate used by silicon cell manufacturers.

For both monocrystalline and multicrystalline silicon, a *semiconductor* connection is made by diffusing phosphorus onto the top of a boron-coated silicon wafer. Contacts are applied to the cell's front and back, with the front contact pattern designed to allow maximum light exposure to the silicon material. The most efficient solar cells use monocrystalline silicon with covered, laser-grooved, grid contacts for maximum light absorption and current.

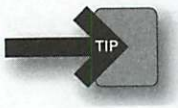
Efficiency

Solar cells function more efficiently under focused light. Unlike common flat-plate PV arrays, concentrator systems need direct sunlight and don't operate in cloudy conditions. They follow the sun's path through the sky using *single-axis tracking*. To follow the sun's changing height seasonally, two-axis tracking is used. For this reason, mirrors and lenses are used to direct light onto specially designed cells with heat sinks or active cell cooling and to disperse the high heat created. An average crystalline silicon cell has an efficiency of 15%, compared to an average thin-film cell with an efficiency of around 6%.

Thin-Wafer Solar Cells

The high cost of crystalline silicon wafers led the semiconductor industry to look for cheaper ways and materials to make solar cells. The most commonly used materials are *amorphous silicon* or *polycrystalline materials* (e.g., cadmium telluride, gallium). These materials strongly absorb light and are about 1 micron thick, so production costs drop.

These thin wafers allow large area deposition (up to 1 meter) and high-volume manufacturing. Thin-film semiconductor layers are deposited onto coated glass or stainless-steel sheets. Intricate thin-film methods have taken about 20 years to get from initial research to prototype manufacturing.



Staebler-Wronski Effect

Amorphous silicon is the best thin-film technology with a single sequence of layers, but output drops (15–35% loss) when exposed to the sun. Not a good thing for *solar* cells! Solar cell degradation is called the *Staebler-Wronski effect.* It describes how the best stability uses the thinnest layers to increase the electric field strength across the material, but reduces light absorption and cell efficiency. The best thin-film cells are low cost, laminated for weather resistance, and have high stable efficiencies and yields.

Electrochemical Solar Cells

While crystalline and thin-film solar cells have solid-state light-absorbing layers, *electrochemical solar cells* use a dye sensitizer to absorb light and produce electron pairs in a nanocrystalline titanium dioxide semiconductor layer. Although cheaper, companies' ability to scale up electrochemical PV cell manufacturing will be proven over time.

Passive Solar

Buildings designed for *passive solar* and day lighting use design features like large south-facing windows and construction materials to absorb and slowly release the sun's heat. No mechanical processes are used in passive solar heating. Incorporating passive solar designs can reduce heating bills as much as 50%. Passive solar designs can also provide cooling through natural ventilation.

Off the Grid

More and more PV installations on homes and buildings are being connected to the electricity grid. Demand is encouraged by governmental programs (Japan and Germany) and incentive pricing and electricity providers (Switzerland and United States). The main push comes from individuals and/or companies who want to get electricity from a clean, nonpolluting, renewable source and agree to pay extra for the option.

An *electricity grid* is an electricity transmission and distribution system, usually supplying power across a wide geographical region.

An individual PV system, connected to a larger supply grid, can supply electricity to a home or building. Any extra electricity can be sent to the grid. Batteries are not needed since the grid is able to meet any extra demand. However, for a home to be independent of the grid, battery storage is needed for power at night.

Grid-connected systems are independent power systems joined to a regional grid that draw on the grid's reserve capacity when they need it and give electricity back during times of extra production.

One disadvantage of solar power is the amount of land needed. For enough solar panels to supply the electricity needs of an urban area, lots of acreage is needed.

Common Uses

Solar home systems are made up of a PV panel, rechargeable battery to store the energy captured during daylight hours, regulator, and necessary wiring and switches. Solar PV modules can be added to a pitched roof above the existing roof tiles, or tiles can be replaced by specially designed PV roof tiles or roof-tiling systems.

Cost-effective PV systems are also great for beach or vacation homes, or remote cabins without access to an electricity grid. Solar energy power is highly reliable and needs little maintenance, making it a great choice for remote sunny locations. Polar research stations are a good example.

Central power applications use solar energy in the same way a traditional utility company operates a major power station. There are hub locations from which power is sent out to meet demand.

Power sent out in small amounts, usually near the point of electrical usage, is known as *distributed power.*

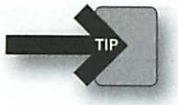
Solar energy is used for industrial applications where only a few kilowatts of power are needed. These applications include powering microwave repeater stations, TV and radio, telemetry and radio telephones, as well as school traffic lights.

Solar power is also used for transportation signaling (navigation buoys, lighthouses, and airstrip warning lights). Environmental monitoring equipment, as well as pipeline corrosion safeguard systems, wellheads, bridges, and other structures also use solar power. Apart from off-grid homes, other remote buildings such as schools, community halls, and clinics all benefit from solar energy to power TV, video, telephone, and refrigeration equipment.

In some rural areas, solar panels are configured as central village power plants, which power homes through a wired network, or act as a battery-charging station where local people can recharge home batteries.

PV systems pump water in remote areas as part of portable water supply systems and desalination plants. Larger off-grid systems are constructed to power higher and more sophisticated electrical loads with an array of PV modules and more battery capacity.

To meet the largest power requirements in an off-grid location, a PV system is sometimes configured with a small diesel generator. This means the PV system no longer has to meet low-sunlight conditions. The diesel generator provides backup power, but is rarely used by the PV system, so fuel and maintenance costs stay low, and diesel use is minimal.



The bottom line is that the Earth gets more energy from the sun in an hour than the planet uses in a whole year. Since 2 billion of the world's people have no access to electricity, solar power is an excellent, renewable, and nonpolluting energy option.

Wind Energy

Wind energy is created by the Earth's atmospheric circulation patterns, which are heated and influenced by the sun. This *green energy* source creates electricity without consuming natural resources or producing greenhouse gases.

Wind power is converted into electricity through large, high-tech turbines built on a high tower to capture the greatest amount of wind. At 30+ meters above the ground, they can catch faster and less turbulent wind. Turbines catch the wind with two to three

Table 17.1 Wind turbines are relatively quiet compared to many modern noises.

SOUND	DECIBEL LEVEL (DB)
Rustling leaves	20
Whispering	25
Library	30
Refrigerator	45
Normal conversation	60
Wind turbine	60
Washing machine	65
Dishwasher	65
Car	70
Vacuum cleaner	70
Busy traffic	75
Alarm clock	80
Noisy restaurant	80
Outboard motor	80
Electric shaver	85
Screaming child	90
Passing motorcycle	90
Live rock music	90–130
Subway train	100
Diesel truck	100
Jackhammer	100
Helicopter	105
Lawn mower	105
Sandblasting	110
Auto horn	120
Airplane propeller	120
Air raid siren	130
Gunshot	140
Jet engine	140
Rocket launch	180

propeller-like blades mounted on a shaft to form a *rotor* that spins a generator, creating electricity. Electricity is sent through power lines to locations far from the turbines.

In the United States, coastal areas, midwestern plains, and mountain passes all funnel and raise wind speeds. In 2012, wind provide 3.2% of the nation's renewable-based electricity. With production tax credits, wind energy could provide 150 gigawatts or 20% of the nation's electricity by 2020.

After the United Nations' Kyoto accord in 1997, 160 industrialized nations committed to lowering average greenhouse emissions (5% below 1990 levels) by 2012, but several nations have since withdrawn support and the accord has stalled. To do this, many nations looked to wind power. Globally, wind energy capacity grew by 29% to reach global installations of 121 gigawatts (GW) and cover 3% of the world's total energy demand. Denmark, the largest user of wind energy, will obtain 35% of its total energy from renewable (half from wind farms) by 2020 and 100% by 2050.

Disadvantages of Wind

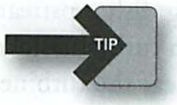
Drawbacks of wind power are unpredictability and the vast acreage needed to generate enough electricity for urban areas. Consequently, land for wind farms, especially in coastal areas, can be expensive and difficult to buy from vacationers. Some opponents also dislike the constant, low, humming noise (60 decibels) caused by wind turbines. Table 17.1 shows where wind turbines fall when compared to other sound producing objects and activities.

Hydroelectric Power

Have you ever tried to cross a rushing creek? Even if the water is only a few inches deep, the force of quickly moving water can knock you over. Flowing water creates energy, which can be turned into electricity. This is called *hydroelectric power* or *hydropower.* The two major ways water flow is used to make electricity are (1) huge amounts of water spinning giant turbines, and (2) tidal diversion where water is directed both up and down pipes linked to turbines (i.e., restricting water flow makes the water flow faster, spinning turbines and generating electricity).

Small hydroelectric power systems can provide enough electricity for a home, farm, or ranch. So for those people lucky enough to live near a river, this is a good way to make electricity. Hydroelectric power doesn't pollute the atmosphere like the burning of fossil fuels coal or natural gas. Moving water is powerful and since hydroelectric plants are fueled by water, it's a clean, generally available fuel source.

Types of Hydroelectric Plants



There are three types of hydroelectric power plants: *impoundment, diversion,* and *pumped storage.* Some of these hydropower plants use dams and some do not.

Hydroelectric power is commonly generated at a power plant dam built on a river, where water is stored in a reservoir. When released from the reservoir, water passes through the dam and spins turbines creating electricity. The water is controlled to provide more or less electricity, or maintain the reservoir level. Figure 17.2 illustrates an impoundment (dam) hydroelectric power plant. Hoover Dam near Las Vegas, Nevada, is an example of an impoundment dam.

A *hydroelectric impoundment plant* holds water in a reservoir and then uses the stored potential energy to drive a turbine and produce electricity when the water is released.

Hydroelectric power doesn't always need a big dam. Some hydroelectric power plants use small canals to channel river water through turbines. This type of hydroelectric power

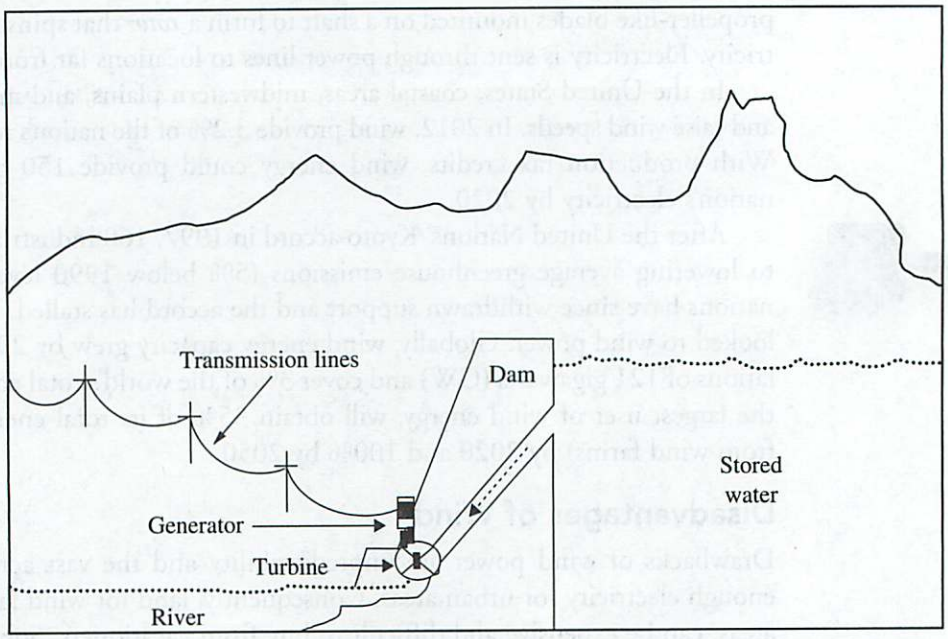


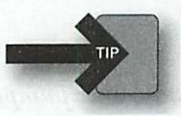
Figure 17.2 A hydroelectric power plant is composed of several parts and processes.

plant is called a *diversion,* or *run-of-river,* plant. It channels a part of a river's flow through a canal or sluice and, depending on the local geography, may not need a dam. Alaska's Tazimina plant is an example of a diversion hydropower plant. No dam is needed.

Some dams, built for irrigation, add a hydroelectric power plant later. In the United States, there are around 80,000 dams. However, only 2,400 produce power. Most dams are for recreation, stock or farm ponds, flood control, water supply, and irrigation. Hydroelectric dams are categorized based on their output of energy. Table 17.2 lists main power divisions.

Hydroelectric Disadvantages

Hydroelectric power plants affect water quality and flow and can cause low dissolved oxygen levels in the water. Drought also affects hydroelectric operations, since plants can't make electricity with low or no water levels. Maintaining normal downstream flow is also important for the survival of marine species and habitats.



Fish are impacted if they aren't able to migrate upstream past impoundment dams to spawning grounds, or if they can't migrate downstream to the ocean. Fish movement can be helped using fish ladders or by collecting and trucking spawning fish upstream. Downstream fish movement is assisted by rerouting fish with screens from turbine intakes, racks, or underwater lights and sounds, and by keeping a very low flow near the turbine.

Table 17.2 There are 3 main classifications of hydroelectric power plants.

HYDROELECTRIC POWER PLANTS	POWER GENERATED
Large	>30 MW
Small hydroelectric power	0.1–30 MW
Micro hydroelectric power	100 kW–0.1 MW

Geothermal Energy

Like solar, the Earth's heat is a gift. The word *geothermal* comes from the Greek words *geo* (earth) and *therme* (heat), and describes the planet's core heat processes from plate tectonics, mountain building, volcanic eruptions, and earthquakes.

The Earth's core temperature is between 4,000°C and 7,000°C. Some internal heat moves upward through tectonic activity and erupts through volcanoes. However, most heat pools into huge underground areas of hot rock, sometimes as big as a mountain range.

The Pacific Ocean is high in geothermal potential. The Atlantic mid-ocean and continental rift zones also have high heat energy (e.g., Iceland and Kenya). Specific hot spots like the Hawaiian Islands and Yellowstone National Park in the United States are also good sources.

Water's Part

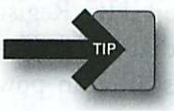
Deep subterranean faults and cracks allow rainwater and snow to seep underground. In high-temperature areas, this water is heated and circulates back to the surface. When rising hot water hits solid rock, it's trapped and fills up the holes and cracks of the surrounding rock, forming a geothermal reservoir. Much hotter than surface hot springs, geothermal reservoirs reach temperatures of over 370°C and are huge energy sources.

To capture geothermal energy, holes are drilled into hot spots and the superheated groundwater is pumped to the surface. Scientists and engineers use geological, electrical, magnetic, geochemical, and seismic tests to help find these reservoirs. They are tapped by drilling exploratory wells, sometimes over two miles deep.

Geothermal Power Generation

In 2012, twenty-five countries around the world were operating geothermal power plants that produced over 1076.7 MW of electricity. These plants provided reliable power for over 60 million people, mostly in developing countries. Today, geothermal power provides about 10% of the U.S. energy supply in the western United States.

Electricity generated in the United States from geothermal resources is more than twice that of solar and wind energy combined. However, it's important to know that geothermal energy is not easily transported and loses up to 90% of its heat energy if not used near its source.



A *geothermal district heating* system supplies heat by pumping geothermal water (60°C or hotter) from one or more wells drilled into a geothermal reservoir. Hot water is sent through a heat exchanger, which transfers the heat to water pumped into buildings through separate pipes. After going through the heat exchanger circuit, the used water is directed back into the reservoir to be reheated.

In the western United States, there are over 275 communities close enough to geothermal reservoirs to take advantage of district heating, with 18 district heating systems in use.

Reykjavik, Iceland, has the world's largest geothermal district heating system. Nearly all the homes and buildings use geothermal heat. Before switching to geothermal heat, Reykjavik was heavily polluted from fossil fuel burning. Now, it is one of the cleanest cities in the world.

Disadvantages of Geothermal

Geothermal energy has few polluting problems itself, but there are processing drawbacks. For example, steam can sometimes bring up heavy metals, sulfur, minerals, salts, radon, and toxic gases. If vented above ground in an open-loop system, geothermal energy production can pollute. Scrubbers filter toxic components, but produce hazardous sludge and can potentially contaminate soil and groundwater. In a closed-loop (recycled) system, pollutants don't come above ground.

Another geothermal drawback involves location, since some geothermal areas, like Yellowstone National Park, are located in pristine, environmentally sensitive areas. Careless construction of geothermal plants could greatly impact local ecology.

Ocean Tidal Energy

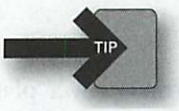
For coastal inhabitants and industries, the ocean offers another renewable energy resource. Incoming and outgoing tides can be tapped with dams across tidal basins, and water movement is used to turn turbines and generate electricity. Although initial construction costs may be high, operating costs are low.

Hydrogen Cells

Hydrogen is considered to be the safest and cleanest of energy sources. Hydrogen is released during *electrolysis* when hydrogen atoms cleave from a water molecule. Then, the hydrogen atoms are stored and used to create electricity through a reversal of the electrolytic process.

Unlike other energy sources, hydrogen fuel cells give off steam as their only waste. However, hydrogen production costs are currently high. For hydrogen to become a viable fuel source, a much cheaper production method will be needed.

Renewable Energy Certificates



Renewable energy certificates (*green certificates* or *green tags*) describe environmental characteristics of power from renewable energy projects and are sold separately from general electricity. Consumers can buy green certificates whether or not they have access to green power through their local utility. They can also buy green certificates without having to switch electricity suppliers. Today, over 30 organizations sell wholesale or retail green energy certificates.

Environmental Resources Trust Inc. (ERT) is a nonprofit organization based in Washington, D.C., that uses market forces to protect and improve the global environment. Established in 1996, ERT uses energy markets to meet the challenges of climate change, secure clean and reliable power, and encourage sustainable land use.

ERT initiated three focused programs to carry out its mission. The GHG Registry validates industrial greenhouse gas emission profiles by creating a market that can facilitate emission decreases. The EcoPower Program verifies and promotes blocks of clean power from new renewable energy sources. The EcoLands Program works out plans to encourage and assist landowners in land use. The bulk of ERT's Clean Power Program involves

1. Verifying specific energy blocks as green and giving them the EcoPower label
2. Creating a *Power Scorecard Rating System* that categorizes the environmental attributes of various clean power blocks
3. Advertising EcoPower blocks and negotiating their sale from generators to consumers, like municipalities
4. Developing an EcoPower ticket program guaranteeing consumers a definite claim to purchased power
5. Auditing EcoPower energy blocks and preparing verification reports

ERT's Power Scorecard Rating System, verification, and marketing have raised public awareness of the clean power market. EcoPower tickets make it possible for clean energy generated in one area to be available for sale elsewhere. Today, legitimate energy providers who advertise clean energy to consumers have each kilowatt-hour verified as "new, certified, zero-emissions renewable power" by ERT.

› Review Questions

Multiple-Choice Questions

1. The Staebler-Wronski effect describes

(A) turbine wind shear factor
(B) greenhouse gas warming
(C) geothermal heat exchange
(D) solar cell degradation
(E) hydroelectric heat loss

2. Geothermal reservoirs can reach temperatures of

(A) 370°C
(B) 560°C
(C) 740°C
(D) 820°C
(E) 1,060°C

3. Impoundment, diversion, and run-of-river are all types of

(A) solar cells
(B) wind turbines
(C) hydroelectric power plants
(D) canoes
(E) nuclear power plants

4. Ethanol is used in the United States as a fuel additive to

(A) increase fuel safety
(B) keep the carburetor new
(C) supplement grain production
(D) reduce incomplete combustion emissions
(E) make gasoline last longer

5. Flowing water that creates energy and is turned into electricity is called

(A) nuclear power
(B) hydroelectric power
(C) solar power
(D) thermal energy
(E) chemical energy

6. Turbines catch the wind with two to three propeller-like blades mounted on a shaft to form a

(A) rotor
(B) heat exchanger
(C) reservoir
(D) magnetic field
(E) storage battery

7. What percent of the world's population uses wood or charcoal as a main energy source?

(A) 15%
(B) 20%
(C) 40%
(D) 50%
(E) 90%

8. When deep underground heat is transferred by thermal conduction through water to the surface, it is called

(A) solar energy
(B) nuclear energy
(C) wind energy
(D) geothermal energy
(E) cosmic energy

9. Propeller-like turbine blades are used to generate electricity from

(A) sunlight
(B) rain
(C) wind
(D) snow
(E) biomass

10. What percent of U.S. energy needs are met by geothermal power?

(A) 10%
(B) 20%
(C) 25%
(D) 35%
(E) 50%

11. A Power Scorecard Rating System categorizes

(A) energy availability
(B) geothermal electricity requirements
(C) turbine rotor speed
(D) environmental aspects of clean power blocks
(E) public acceptance of tidal energy

12. Tidal energy taps

(A) stream flow
(B) incoming and outgoing tides
(C) salinity levels
(D) rising geothermal magma
(E) melting icebergs

13. Industrial greenhouse gas emission profiles are products of which nonprofit organization?

(A) International Oil Tanker Owner's Pollution Federation
(B) GHG Registry
(C) Superfund
(D) Occupational Safety and Health Agency
(E) EcoPower

14. Diffusing phosphorus onto boron-coated silicon wafers produces

(A) acetate
(B) hydroelectric conduits
(C) semiconductor connections
(D) radioactive markers
(E) an electricity grid

15. All the following are good sites for wind turbines except

(A) forests
(B) coastal areas
(C) plains
(D) mountain passes
(E) open ocean

16. The problem with ethanol is its ability to

(A) cause soil erosion
(B) pollute drinking water
(C) evaporate into the atmosphere
(D) increase the polluting effects of other compounds
(E) reduce organic compounds

17. What element is released during electrolysis?

(A) Sulfur
(B) Nitrogen
(C) Helium
(D) Radon
(E) Hydrogen

18. What safe fuel offers superior performance and is the fuel of choice for race cars?

(A) Hydrogen
(B) Methanol
(C) Gasohol
(D) Ethanol
(E) Propane

19. The Earth gets more energy from the sun in an hour than

(A) New York City uses in a month
(B) Asia uses in a week
(C) the planet uses in a year
(D) the Pacific Ocean can absorb
(E) photovoltaic cells can tolerate

Answers and Explanations

1. **D**—The Staebler-Wronski effect describes solar cell degradation (i.e., the thinnest layers increase the electric field strength across the material, but reduce light absorption and cell efficiency).
2. **A**—Geothermal reservoirs can reach temperatures of 370°C.
3. **C**—Impoundment and diversion or run-of-river are types of hydroelectric dams.
4. **D**—Ethanol is used in the United States as a fuel additive to reduce incomplete combustion, burn cleanly, and reduce greenhouse gases.
5. **B**—Flowing water (*hydro*) creates energy and is turned into electricity.
6. **A**—Turbines catch the wind with two or three propeller-like blades mounted on a shaft to form a rotor attached to a power generator.
7. **C**—Forty percent of the world's population uses wood or charcoal as their main energy source.
8. **D**—Deep underground heat, transferred by thermal conduction through water to the surface, is called geothermal (Earth's heat) energy.
9. **C**—Airplane-like propeller blades are used to generate electricity from wind turbines.
10. **A**—Because of location, 10% of U.S. energy comes from geothermal power.
11. **D**—A Power Scorecard Rating System categorizes environmental aspects of verified clean power blocks from new renewable energy sources.
12. **B**—Tidal energy taps incoming and outgoing water flow during high and low tides.
13. **B**—Industrial greenhouse gas emission profiles are products of the GHG Registry.
14. **C**—Diffusing phosphorus onto boron-coated silicon wafers produces semiconductor connections.
15. **A**—Coasts, plains, mountain passes, and open oceans are good for wind turbines, but forests tend to block or disperse wind.
16. **D**—The problem with ethanol is its ability to increase benzene and toluene's time in the environment before they break down.
17. **E**—Hydrogen is released as a result of hydrolysis.
18. **B**—Because of clean burning, methanol provides race cars with superior performance and safety.
19. **C**—The Earth gets more energy from the sun in an hour than the planet uses in a year (i.e., roughly 10,000 times all the commercial energy produced yearly).

Free-Response Questions

1. The European Wind Energy Association plans to provide over 10% of Europe's electricity by 2030. Denmark's wind energy program shows how government support can assist in making green energy sources commercially viable. Its wind energy program provided 35% of Denmark's energy needs in 2012.

   In the United States, 11,329 MW of wind energy were generated in 2006, with additional wind capacity coming on line. With an energy cost of 2.0 cents/kWh, wind is equal to or less expensive than coal, oil, nuclear, and most natural gas–fired generation. The great thing about wind, besides being a clean energy source, is that it's free after initial construction.

   (a) Describe possible disadvantages of wind-generated electricity.
   (b) List the long-term benefits of wind energy.

2. ERT is made up of the National Audubon Society, the National Fish and Wildlife Foundation, Environmental Defense, and the German Marshall Fund. ERT energizes green power markets by supplying important auditing and verification services. These services support consumer confidence by verifying that new green power sources are actually being brought on line.

   (a) Describe how the Power Scorecard Rating System works.
   (b) How do EcoPower blocks benefit consumers?

Free-Response Answers and Explanations

1.

a. Wind energy disadvantages are mainly socioeconomic. Though the monetary costs of building wind turbines is going down, wind energy is not yet an economically efficient way to produce electricity on a mass scale. While wind is readily available all over the world, it is both unpredictable and not strong enough in all areas as a source of electricity. Creating the necessary number of turbines to produce electricity for urban areas requires extensive land use and creates noise pollution for nearby populations. Wind farms also detract from the natural beauty of their locales, thus devaluing a land's scenic value. This could become an economic burden rather than boon, particularly in coastal areas where tourism provides a much needed source of revenue.

b. Wind energy is a clean, renewable energy resource that does not contribute to the creation of greenhouse gases like CO_2. Using wind energy places much less stress on the surrounding environment than other energy production methods. Wind energy also has long-term social and economic benefits. Because its "fuel" is free and inexhaustible, its use can reduce and therefore help stabilize the demands on other valuable resources such as natural gas and oil. Wind energy can generate electricity for remote areas marginalized by geographic locale, and improve the quality of life for populations all over the world. Finally, because of the low environmental impact of turbines, the land beneath turbines can be used for multiple purposes (e.g., agriculture), allowing maximum land use.

2.

a. Developed by the Environmental Resources Trust, the Power Scorecard Rating System categorizes electricity products according to their environmental impact and commitment to new renewable energy. This ratings system creates a value structure that places a premium on new renewable energy products that minimize environmental impact. It helps ERT harness the power of the economy to not only raise public awareness of new, clean energy resources, but stimulate clean energy business allowing market forces to provide businesses the incentives to use clean energy.

b. One benefit EcoPower blocks give to consumers is the ability to "speak" through economic means. By informing consumers about clean energy products and resources, EcoPower blocks help bridge the gap between existing clean energy producers and lack of public information. EcoPower blocks clearly define and provide assurances about clean energy products. The EcoPower program harnesses market forces to drive positive global environmental changes and gives consumers the ability to promote clean energy through buying power.

› Rapid Review

- The Staebler-Wronski effect describes solar cell degradation (i.e., the thinnest layers increase the electric field strength across the material, but reduce light absorption and cell efficiency).
- Geothermal reservoirs can reach temperatures of 370°C.
- Impoundment and diversion or run-of-river are types of hydroelectric dams.
- Ethanol is used in the United States as a fuel additive to reduce incomplete combustion, allow the fuel to burn cleanly, and reduce greenhouse gases.
- Flowing water (*hydro*) creates energy and can be turned into electricity.
- Turbines catch the wind with two to three propeller-like blades mounted on a shaft to form a rotor attached to a power generator.
- Forty percent of the world's population uses wood or charcoal as a main energy source.
- Deep underground heat, transferred by thermal conduction through water to the surface, is called geothermal (Earth's heat) energy.
- Airplane-like propeller blades are used to generate electricity from wind turbines.
- Taking advantage of location, 10% of U.S. energy comes from geothermal power.
- A Power Scorecard Rating System categorizes environmental aspects of verified clean power blocks from new renewable energy sources.
- Tidal energy taps incoming and outgoing water flow during high and low tides.
- Industrial greenhouse gas emission profiles are products of the GHG Registry.
- Diffusing phosphorus onto boron-coated silicon wafers produces semiconductor connections.
- Coasts, plains, mountain passes, and open oceans are good for wind turbines, but forests tend to block or disperse the wind.
- The problem with ethanol is its ability to increase benzene and toluene's time in the environment before they break down.
- Hydrogen is released as a result of hydrolysis.
- Because it burns cleanly, methanol provides race cars with superior performance and safety.
- The Earth gets more energy from the sun in an hour than the planet uses in a year (i.e., roughly 10,000 times all the commercial energy produced yearly).