

### 3.5 ENERGY SOURCES TOMORROW

An *alternative source of energy* is one that is different from the typical sources used today. The sources used today are the fossil fuels (coal, petroleum, and natural gas), nuclear, and falling water. Alternative sources could be solar, geothermal, hydrogen gas, fusion, or any other energy source that a new technology could utilize.

#### SOLAR TECHNOLOGIES

The term *solar energy* is used to describe a number of technologies that directly or indirectly utilize sunlight as an alternative energy source (Figure 3.21). There are eight main categories of these solar technologies:

1. **Solar cells.** A solar cell is a thin crystal of silicon, gallium, or some polycrystalline compound that generates electricity when exposed to light. Also called *photovoltaic devices*, solar cells have no moving parts and produce electricity directly, without the need for hot fluids or intermediate conversion states. Solar cells have been used extensively in space vehicles and satellites, and are now being used to create electricity in large-scale, Earth-based power plants. In the past, the difficulty to producing solar cells had limited their use to demonstration projects, remote site applications, and consumer specialty items such as solar-powered watches and calculators. Research and development has now allowed the manufacture of large solar cells at an affordable cost. See A Closer Look: Solar Cells to find out how a solar cell is able to create a current.
2. **Power tower.** This is another solar technology designed to generate electricity, by using sunlight to create heat, which can then be used to turn turbines. In most power tower plans, a large collection of mirrors, called *heliostats*, are used to focus sunlight on a central tower. The top of the tower holds a boiler where liquified salts (a mixture of sodium nitrate and potassium nitrate) can be heated to about 566°C (about 1,050°F). This molten salt will be pumped to a steam generator, and the steam will be used to drive an electric generator, just as in other power plants. Water could also be heated directly in the power tower boiler, but molten salt is used because it can be stored in an insulated storage tank for use when the Sun is not shining, perhaps for up to 20 hours. The US National Renewable Energy Laboratory (NREL) estimates that electricity could be produced from power towers for 5.47 cents per kWh, by the year 2020.
3. **Passive application.** In passive applications, energy flows by natural means, without mechanical devices such as motors, pumps, and so forth. A passive solar house would include such considerations as the orientation of a house to the Sun, the size and positioning of windows, and a roof overhang that lets sunlight in during the winter but keeps it out during the summer. There are different design plans to capture, store, and distribute solar energy throughout a house, and some of these designs are described in A Closer Look: Passive Solar Design.
4. **Active application.** An active solar application requires a solar collector in which sunlight heats air, water, or some liquid. The liquid or air is pumped through pipes in a house to generate electricity, or it is used directly for hot water. Solar water heating makes more economic sense today than the other applications. Both active and passive forms of solar water heaters are now being incorporated into house designs, and are even required in new home construction in some locations.
5. **Wind energy.** The wind has been used for centuries to move ships, grind grain into flour, and pump water. The wind blows, however, because radiant energy from the Sun heats some parts of Earth's surface more than other parts. This differential heating results in pressure differences and the horizontal movement of air, which is called wind. Thus, wind is another form of solar energy. Wind turbines are used to generate electrical energy or mechanical energy. The biggest problem with wind energy is the inconsistency of the wind. Sometimes the wind speed is too great, and other times it is not great enough. Several methods of solving this problem are being researched (see Science and Society: Use Wind Energy?).
6. **Biomass.** Biomass is any material formed by photosynthesis, including small plants, trees, and crops, and any garbage, crop residue, or animal waste. Biomass can be burned directly as a fuel, converted into a gas fuel (methane), or converted into liquid fuels such as alcohol. The problem with using biomass includes the energy expended in gathering the biomass and the energy used to convert it to a gaseous or liquid fuel.



**FIGURE 3.21** Wind is another form of solar energy. This wind turbine generates electrical energy for this sailboat, charging batteries for backup power when the wind is not blowing. In case you are wondering, the turbine cannot be used to make a wind to move the boat. In accord with Newton's laws of motion, this would not produce a net force on the boat. *Source:* © Bill W. Tillery.

7. **Agriculture and industrial heating.** This is a technology that simply uses sunlight to dry grains, cure paint, or do anything that can be done with sunlight rather than using traditional energy sources.
8. **Ocean thermal energy conversion (OTEC).** This is an electric generating plant that uses the temperature difference between the surface and the depths of tropical, subtropical, and equatorial ocean waters. Basically, warm water is drawn into the system to vaporize a fluid, which expands through a turbine generator. Cold water from the depths condenses the vapor back to a liquid form, which is then cycled back to the warm-water side. The concept has been tested and found to be technically successful. The greatest interest in using it seems to be among islands that have warm surface waters (and cold depths) such as Hawaii, Puerto Rico, Guam, and the Virgin Islands.

## GEOTHERMAL ENERGY

**Geothermal energy** is energy from beneath Earth's surface. The familiar geysers, hot springs, and venting steam of Yellowstone National Park are clues that this form of energy exists. There is substantially more geothermal energy than is revealed in Yellowstone, however, and geothermal resources are more widespread than once thought. Earth has a high internal temperature, and recoverable geothermal resources may underlie most states. These resources occur in four broad categories of geothermal energy: (1) dry steam, (2) hot water, (3) hot, dry rock, and (4) geopressurized resources. Together, the energy contained in these geothermal resources represents about 15,000 times more energy than is consumed in the United States in a given year. The only problem is getting to the geothermal energy, then using it in a way that is economically attractive.

Most geothermal energy occurs as *hot, dry rock*, which accounts for about 85 percent of the total geothermal resource. Hot, dry rock is usually in or near an area of former volcanic activity. The problem of utilizing this widespread resource is how to get the energy to the surface. Research has been conducted by drilling wells, then injecting water into one well and extracting energy from the heated water pumped from the second well. There is greater interest in the less widespread but better understood geothermal systems of hot water and steam.

*Geopressurized resources* are trapped underground reservoirs of hot water that contain dissolved natural gas. The water temperature is higher than the boiling point, so heat could be used as a source of energy as well as the dissolved natural gas. Such geopressurized reservoirs make up about 14 percent of the total accessible geothermal energy found on Earth. They are still being studied in some areas since there is concern over whether the reservoirs are large enough to be economically feasible as an energy source. More is known about recovering energy from other types of hot water and steam resources, so these seem more economically attractive.

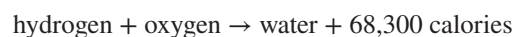
Hot water and steam comprise the smallest geothermal resource category, together making up only about 1 percent of the total known resource. However, more is known about the utilization and recovery of these energy sources, which are estimated to

contain an amount of energy equivalent to about one-half of the present known reserve of petroleum in the United States. *Steam* is very rare, occurring in only three places in the United States. Two of these places are national parks (Lassen and Yellowstone), so this geothermal steam cannot be used as an energy source. The third place is at the Geysers, an area of fumaroles near San Francisco, California. Steam from the Geysers is used to generate a significant amount of electricity.

Hot water systems make up most of the *recoverable* geothermal resources. Heat from deep volcanic or former volcanic sources creates vast, slow-moving convective patterns in groundwater. If the water circulating back near the surface is hot enough, it can be used for generating electricity, heating buildings, or many other possible applications. Worldwide, geothermal energy is used to operate pulp and paper mills, cool hotels, raise fish, heat greenhouses, dry crops, desalt water, and do dozens of other things. Thousands of apartments, homes, and businesses are today heated geothermally in Oregon and Idaho in the United States, as well as in Hungary, France, Iceland, and New Zealand. Today, understand that each British thermal unit supplied by geothermal energy does not have to be supplied by fossil fuels. Tomorrow, you will find geothermal resources becoming more and more attractive as the price and the consequences of using fossil fuels continue to increase.

## HYDROGEN

Hydrogen is the lightest and simplest of all the elements, occurring as a diatomic gas that can be used for energy directly in a fuel cell or burned to release heat. Hydrogen could be used to replace natural gas with a few modifications of present natural gas burners. A big plus in favor of hydrogen as a fuel is that it produces no pollutants. In addition to the heat produced, the only emission from burning hydrogen is water, as shown in the following equation:



The primary problem with using hydrogen as an energy source is that *it does not exist* on or under Earth's surface in any but trace amounts! Hydrogen must therefore be obtained by a chemical reaction from such compounds as water. Water is a plentiful substance on Earth, and an electric current will cause decomposition of water into hydrogen and oxygen gas. Measurement of the electric current and voltage will show that



Thus, assuming 100 percent efficiency, the energy needed to obtain hydrogen gas from water is exactly equal to the energy released by hydrogen combustion. So hydrogen cannot be used to produce energy, since hydrogen gas is not available, but it can be used as a means of storing energy for later use. Indeed, hydrogen may be destined to become an effective solution to the problems of storing and transporting energy derived from solar energy sources. In addition, hydrogen might serve as the transportable source of energy, such as that needed for cars and trucks, replacing the fossil fuels. In summary, hydrogen has the potential to provide clean, alternative energy for a number of uses, including lighting, heating, cooling, and transportation.