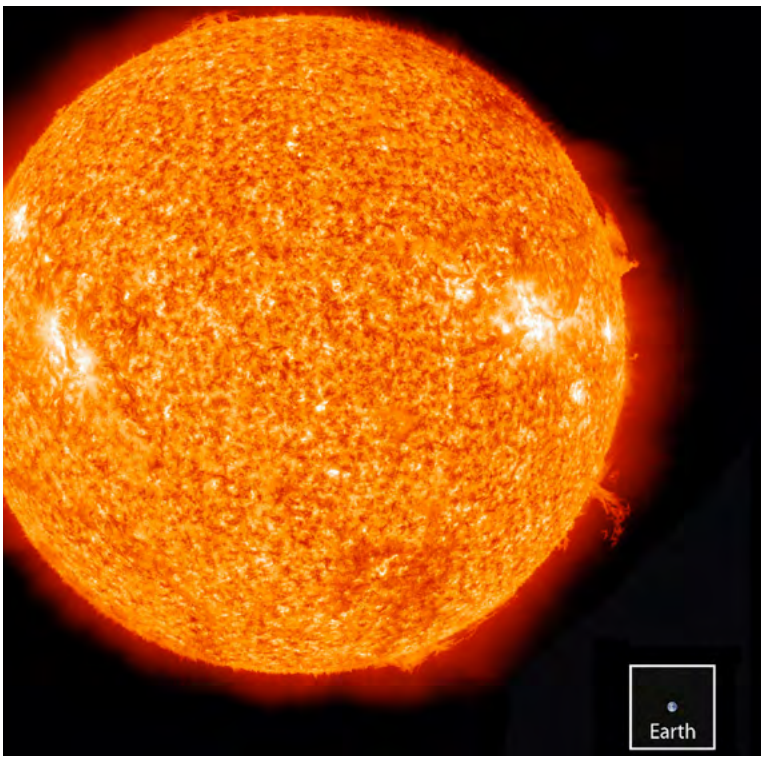


Chapter 17

Capturing Energy

THE MAIN IDEA

Dirty energy is most convenient, and clean energy is most abundant.

17.6 Biomass Is Chemical Energy

Plants use photosynthesis to convert radiant solar energy to chemical energy. This chemical energy comes in the form of the plant material itself—**biomass**. We can use the energy of biomass in two ways: process it to produce transportable fuels or burn it at a properly equipped power plant to produce electricity. Biomass can be grown on demand in regions where water supplies are abundant. If biomass is produced at a sustainable rate, the carbon dioxide released when it is burned balances the carbon dioxide consumed during photosynthesis. Biomass combustion products generally contain about one-third the ash produced by coal and about one-thirtieth the sulfur.

Fuels Can Be Obtained from Biomass

The U.S. transportation industry is mostly dependent on petroleum and consumes mostly of all petroleum stockpiles. Fuels from biomass, notably ethanol, are natural alternatives to petroleum-based fuels. In fact, ethanol has a higher octane rating than gasoline, which is why it is a preferred fuel for race-car drivers. Ethanol was also the preferred fuel of automotive pioneers Henry Ford and Joseph Diesel, who originally intended their automobiles to run on biofuels. By a curious coincidence, ethanol from fermented grains was about to be used by the automobile industry just prior to the passage of the 18th amendment to the U.S. Constitution prohibiting the consumption of ethanol. Prohibition allowed the petroleum industry to take over.

Today in the United States, government programs requiring the addition of 10 percent ethanol to gasoline are becoming widespread. Ethanol, also known as grain alcohol, can be prepared from the fermentation of food biomass—any grain will do, but those rich in simple carbohydrates such as sugars work best (**Figure 17.28**).

READING CHECK

When does the combustion of biomass not contribute to the net production of carbon dioxide, which is a greenhouse gas?

Λ Figure 17.28

Gasohol is gasoline containing an alcohol additive. The alcohol provides an octane boost, allowing an engine to run more efficiently with less pollution. If the alcohol is produced from biomass grown within a nation, there is the added benefit of a reduced dependence on foreign oil.

Figure 17.29 >

Brazil's sugar mills produce sugar as well as ethanol.

In 2020, worldwide production of ethanol for fuel was over 95 billion liters. Of that, the United States was the leading producer (53 billion L) followed by Brazil (30 billion L). While ethanol is produced in the United States primarily from the fermentation of corn, in Brazil, it is produced primarily from the fermentation of sugar cane. Brazil started its ethanol for fuel program decades ago in response to the oil crisis of the 1970s. Up until 2005, it was the world's leading producer (**Figure 17.29**). Notably, most vehicles in Brazil are equipped to run using E25 or higher, which is fuel containing 25% ethanol. Thus, the carbon dioxide produced from these vehicles is offset by the carbon dioxide absorbed by the growing sugar cane.

Ethanol from fermentation is relatively expensive because of the great financial and environmental costs of growing food biomass, a process that requires vast amounts of water and fertilizer. Ethanol derived from petroleum is actually less expensive, but only because crude oil prices are kept artificially low. If taxpayer subsidies, exemptions from paying for the environmental damage from mining and drilling, and the cost of military protection are factored in, the price of crude oil increases significantly.

The ultimate starting material for the creation of ethanol is cellulose, which is the world's most abundant organic chemical, found in all plants. The idea is to break cellulose down to its glucose monomers, which can then be fermented to form ethanol. As discussed in Chapter 13, however, the cellulose found in plants is tightly locked. This is important for a plant's structural rigidity, but it makes it very difficult to break down the cellulose into glucose. Nonetheless, much research is being conducted to discover ways in which this can be done in a cost-effective and environmentally friendly manner. One promising approach is to cook the cellulose in liquid ammonia, NH_3. Other approaches involve mimicking the cellulose-digesting action of the microbes that perform this feat within the stomachs of termites and ruminants, such as cows and goats. Ethanol from cellulose is sometimes called cellulosic ethanol or grassohol. An advantage of cellulosic ethanol is that it does not use up food-stocks such as corn and sugar that could be used instead to help alleviate world hunger.

fyi FOR YOUR INFORMATION

Does biomass sound reminiscent of fossil fuels? it should, because biomass is simply a fossil fuel without the fossil—dead plant material that has yet to turn into coal, petroleum, or natural gas. Just about anything you can do with fossil fuels, you can do with biomass, except, of course, deplete it and create as much pollution.

Biomass Can Be Burned to Generate Electricity

Converting biomass to a transportable fuel is an extra step that decreases energy efficiency. Higher efficiencies are obtained by burning the biomass

directly to produce electricity, also known as biopower. Most biopower is generated by paper companies and forest products companies using wood and wood wastes as fuel. Some municipalities use solid-waste incinerators that provide electricity and waste disposal simultaneously. (On average, about 80 percent of the dry weight of municipal solid waste is combustible organic material.)

The traditional approach to generating electricity from biomass is to burn the biomass in a boiler, where water is converted to steam used to drive a steam turbine. Efficiency can be more than doubled by first converting the biomass to a gaseous fuel, which may be done by applying air and steam at high pressure. Alternatively, gaseous fuels are also produced by mixing the biomass with very hot sand, as is done at the Vermont facility shown in **Figure 17.30**. The gaseous fuel is burned, and the hot combustion products are directed to a gas turbine that generates electricity. In addition, the exhaust gases from the turbine can be used to produce steam for industrial applications or for additional power generation.

In the United States, electricity produced from biomass has since remained fairly constant over the past couple decades. A reason for this is because, as a renewable energy, biopower faces stiff competition from photovoltaics and wind. Consider that about half of all biopower within the United States is generated within California. As shown in **Figure 17.31**, the production of biopower in California has remained fairly steady, while electric power from photovoltaics and wind have grown remarkably. We explore the reasons for this in the next chapter section.

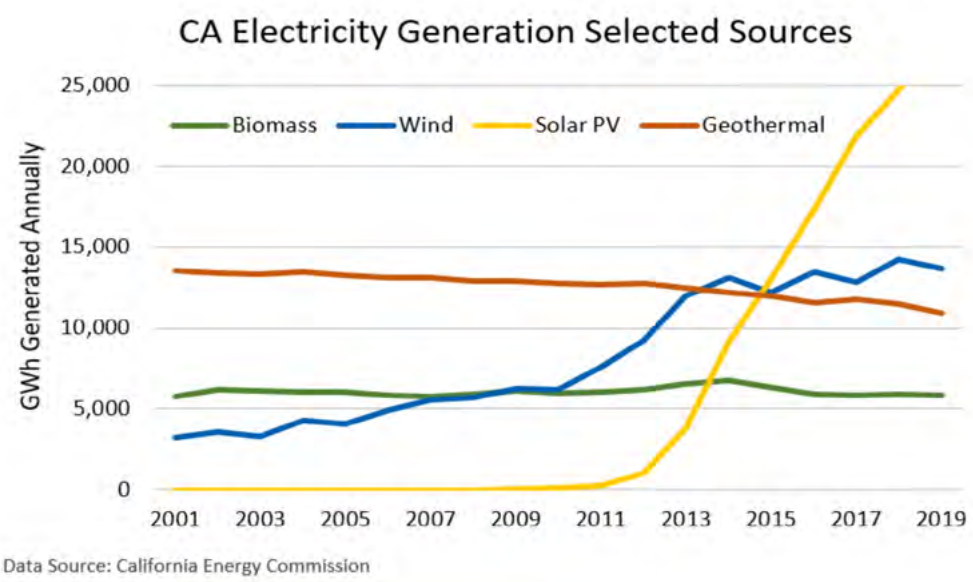
Λ Figure 17.30

Since 1984, the Vermont Biomass Gasification Project has supplied more than 50 MW of electricity to the Burlington, Vermont area. The electricity is generated by gas turbines powered by the combustion of a gaseous fuel mixture created as wood chips are mixed with very hot sand (1000°C).

CONCEPT **CHECK**

What do biomass and fossil fuels have in common?

CHECK YOUR ANSWER They both originate from solar energy.



Λ Figure 17.31

This graph shows the electrical power generated from renewable sources in California. While geothermal and biomass have held steady, wind and photovoltaics (PV) have risen steeply.