



Biomass

What Is Biomass?

Biomass is any organic matter—wood, crops, seaweed, animal wastes—that can be used as an energy source. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food.

Biomass gets its energy from the sun. All organic matter contains stored energy from the sun. During a process called **photosynthesis**, sunlight gives plants the energy they need to convert water and **carbon dioxide** into oxygen and sugars. These sugars, called **carbohydrates**, supply plants and the animals that eat plants with energy. Foods rich in carbohydrates are a good source of energy for the human body.

Biomass is a **renewable** energy source because its supplies are not limited. We can always grow trees and crops, and waste will always exist.

Types of Biomass

Nearly any organic matter can be used as an energy source. Most biomass used today is domestically produced. We use several types of biomass, including wood, agricultural products, solid waste, landfill gas and biogas, and biofuels.

■ Wood

Waste wood products—logs, chips, bark, and sawdust—account for 41 percent of biomass energy. Wood and wood waste are used as a heat source and to generate electricity. A very small percentage of homes use wood as its heating fuel. Most of the waste wood products are used by industries making the waste to generate electricity. This electrical power is not distributed by utilities, but is used in a process called cogeneration. Paper mills and saw mills use much of their waste products to generate steam and electricity for their use. However, since they use so much energy, they still need to buy additional electricity from utilities.

Increasingly, timber companies and companies involved with wood products are seeing the benefits of using their lumber scrap and sawdust for power generation. This saves disposal costs and, in some areas, may reduce the companies' utility bills. In fact, the pulp and paper industries rely on biomass for well over half of their energy needs. Other industries that use wood biomass for energy include lumber producers, furniture manufacturers, agricultural businesses like nut and rice growers, and liquor producers.

■ Solid Waste

Burning trash turns waste into a usable form of energy. One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas.

Power plants that burn garbage for energy are called **waste-to-energy plants**. These plants generate electricity just as coal-fired plants do, except that combustible garbage—not coal—is the fuel used to fire their boilers. Making electricity from garbage costs more than making

Biomass at a Glance, 2022

Classification:

- renewable

Major Uses:

- industry, transportation fuel, electricity

U.S. Energy Consumption:

- 4.827 Q
- 5.10%

U.S. Energy Production:

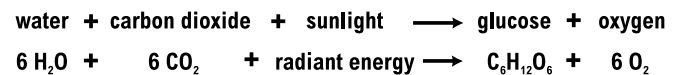
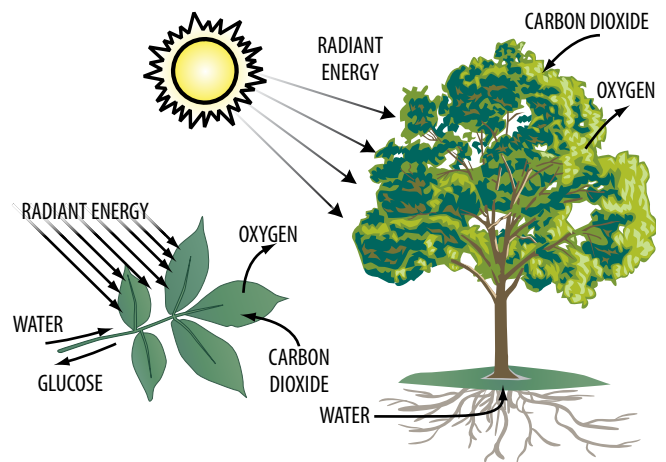
- 5.044 Q
- 5.15%

(Most electricity from biomass is for cogeneration, and is not included in these numbers.)

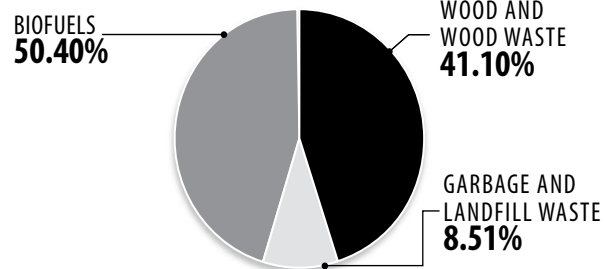
Data: Energy Information Administration

Photosynthesis

In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).



U.S. Sources of Biomass, 2022



Data: Energy Information Administration

* Total may not equal 100% due to independent rounding.

it from coal and other energy sources. The main advantage of burning solid waste is that it reduces the volume of garbage dumped in landfills by up to 90 percent, which in turn reduces the cost of landfill disposal. It also makes use of the energy in the garbage, rather than burying it in a landfill, where it remains unused.

▪ Landfill Gas and Biogas

Bacteria and fungi are not picky eaters. They eat dead plants and animals, causing them to rot or decay. A fungus on a rotting log is converting **cellulose** to sugars to feed itself. Although this process is slowed in a landfill, a substance called **methane** gas is still produced as the waste decays.

Regulations require landfills to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is not harmless. The gas can cause fires or explosions if it seeps into nearby homes and is ignited. Landfills can collect the methane gas, purify it, and use it as fuel to generate electricity.

Methane, the main ingredient in natural gas, is a good energy source. Many stoves and furnaces use methane supplied by utility companies. In 2003, East Kentucky Power Cooperative began recovering methane from three landfills. The utility now uses the gas at six landfills to generate enough electricity to power more than 8,000 Kentucky homes. Over 500 facilities across the country use their landfill gas for electricity, with potential for more.

However, still only a small portion of landfill gas is used to provide energy. Most is burned off at the landfill. With today's low natural gas prices, this higher-priced **biogas** is less economical to collect. Methane, however, a more potent greenhouse gas than carbon dioxide, is an estimated 28 times better at trapping heat in the atmosphere. It is better for the environment to burn landfill methane and change it into carbon dioxide through combustion than to release it into the atmosphere.

Methane can also be produced using energy from agricultural and human wastes. **Biogas digesters** are airtight containers or pits lined with steel or bricks. Waste put into the containers is fermented without oxygen present to produce a methane-rich gas. This gas can be used to produce electricity, or for cooking and lighting. It is a safe and clean-burning gas, producing little carbon monoxide and no smoke.

Biogas digesters are inexpensive to build and maintain. They can be built as family-sized or community-sized units on farms, at water treatment facilities, and at landfills. They need moderate temperatures and moisture for the fermentation process to occur. For developing countries, biogas digesters can be one of the best answers to many of their energy needs. They can help reverse the rampant deforestation caused by wood-burning, reduce air pollution, fertilize overused fields, and produce clean, safe energy for rural communities.

Use of Biomass

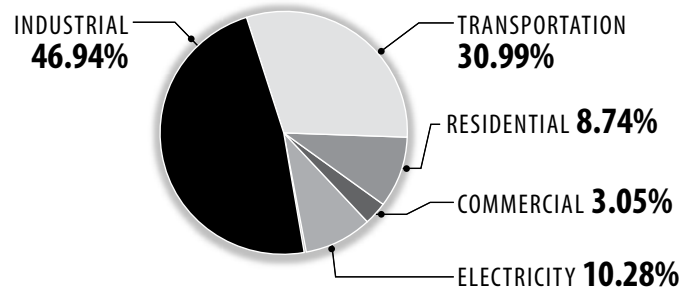
Until the mid-1800s, wood gave Americans 90 percent of the energy used in the country. In 2022, biomass provided 5.10 percent of the total energy we consumed. Biomass has largely been replaced by natural gas and petroleum.

Forty-one percent of the biomass used today comes from burning wood and wood scraps such as sawdust. About 50 percent is from **biofuels**, principally ethanol, that are used as a gasoline additive or alternative. The rest comes from crops, garbage, and landfill gas.

Industry is the biggest user of biomass. About half of biomass is used by industry. Electric utilities use ten percent of biomass for power generation. In turn, biomass produces 1.26 percent of the electricity we use.

Transportation is the next biggest user of biomass; about 31 percent of biomass is used by the transportation sector to produce biofuels like **ethanol** and **biodiesel** (see pages 12-13).

U.S. Biomass Consumption by Sector, 2022



Data: Energy Information Administration
*Total may not equal 100% due to independent rounding.

Using Biomass Energy

Usually we burn wood and use its energy for heating. We can burn biomass in waste-to-energy plants to produce steam for making electricity, or we can burn it to provide heat for industries and homes. Burning, however, is not the only way to convert biomass energy into a usable energy source. There are three other ways:

Fermentation: There are several types of processes that can produce an alcohol (ethanol) from various plants, especially corn. The two most commonly used processes involve using yeast to ferment the starch in the plant to produce ethanol. One of the newest processes involves using enzymes to break down the cellulose in the plant fibers, allowing more ethanol to be made from each plant, because all of the plant tissue is utilized, not just the starch.

Bacterial Decay: Bacteria feed on dead plants and animals, producing methane. Methane is produced whenever organic material decays. Methane is the main ingredient in natural gas, the gas sold by natural gas utilities. Landfills can recover and use the methane gas produced by the garbage.

Conversion: Biomass can be converted into gas or liquid fuels by using chemicals or heat. In India, cow manure is converted to methane gas to produce electricity. Methane gas can also be converted to methanol, a type of alcohol made from fermenting wood. Methane and methanol each have only one carbon atom.

The residential sector uses about nine percent of the biomass supply. The most recently reported data showed about two percent of American homes use wood as the only source of heat. Most of these homes burn wood in fireplaces and wood stoves for heat.

Biomass and the Environment

Environmentally, biomass has some advantages over fossil fuels such as coal and petroleum. Biomass contains little sulfur and nitrogen, so it does not produce the pollutants that can cause **acid rain**. Burning biomass releases carbon dioxide, but growing plants for use as biomass fuels may also help keep carbon dioxide levels balanced. Plants remove carbon dioxide—a **greenhouse gas**—from the atmosphere when they grow.



Biofuels: Ethanol

What Is Ethanol?

Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol. The majority of the ethanol produced in the United States comes from corn. New technologies are producing ethanol from cellulose in woody fibers from trees, grasses, and crop residues.

Today nearly all of the gasoline sold in the U.S. contains around 10 percent ethanol and is known as E10. In 2011, the U.S. Environmental Protection Agency (EPA) approved the introduction of E15 (15 percent ethanol, 85 percent gasoline) for use in passenger vehicles from model year 2001 and newer. Fuel containing 85 percent ethanol and 15 percent gasoline (E85) qualifies as an alternative fuel. Vehicles that can burn E85 and gasoline have been designated as flexible-fuel vehicles, or simply flex-fuel. When flex-fuel vehicles were introduced, they were sold as a more environmentally-friendly option as compared to conventional gasoline-powered vehicles because of their use of high amounts of ethanol. As many as 21 million flex-fuel vehicles were on the road at one point. However, flex-fuel vehicles have been declining in popularity due in part to the reduced fuel efficiency when burning E85 and also to the shift toward electric vehicles. In 2022, just over 20 million flex-fuel vehicles were in use, but it is estimated that many do not regularly use E85.

Characteristics of Ethanol

With one of the highest octane ratings of any transportation fuel, ethanol increases the energy efficiency of an engine. When using ethanol blends, vehicles have comparable power, acceleration, payload capacity, and cruising speed to those using gasoline. However, because ethanol contains less energy per gallon than gasoline; fuel efficiency, or distance traveled on one gallon of fuel, is slightly less. Ethanol is also less flammable than gasoline; it is safer to store, transport, and refuel.

Vehicle maintenance for ethanol-powered vehicles is similar to those using gasoline. Oil changes, in fact, are needed less frequently. Due to its detergent properties, ethanol tends to keep fuel lines and injectors cleaner than gasoline. Because ethanol has a tendency to absorb moisture, using ethanol fuel can help reduce the possibility of fuel-line-freeze-up during the winter.

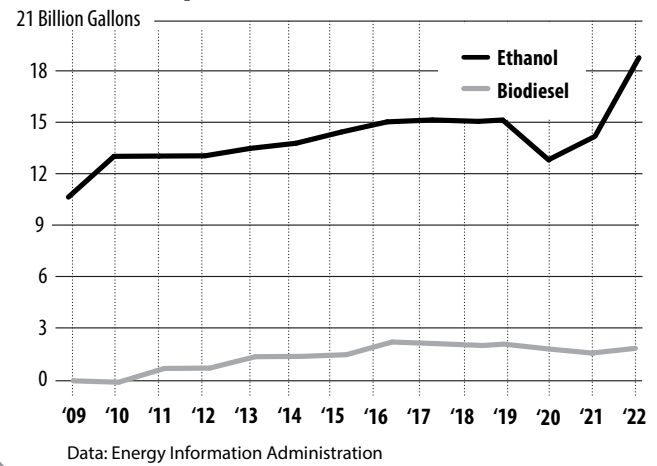
Distribution of Ethanol

In 2023, ethanol plants in the U.S. produced more than 17 billion gallons of ethanol. There are 187 plants operating nationwide. These plants are located mostly in the Midwest. There are currently over 4,400 E85 fueling stations in 42 states. Ethanol fuels for heavy-duty applications are available only through bulk suppliers.

Economics of Ethanol

The Federal Government mandated that by 2012, 12 billion gallons of renewable fuels be produced per year. The U.S. is exceeding this mark, producing 17.663 billion gallons of ethanol alone in 2023. For comparison, however, the U.S. consumed over 135 billion gallons of gasoline in 2023. Today, it costs more to produce ethanol than gasoline, however, federal and state tax advantages make ethanol competitive in the marketplace.

U.S. Consumption of Biofuels, 2022



Since it is the second largest use of corn, ethanol production adds value to crops for farmers. As new technologies for producing ethanol from all parts of plants and trees become cost-effective, the production and use of ethanol will increase dramatically.

Environmental Impacts

Ethanol is both water soluble and biodegradable. If a fuel spill occurs, the effects are less environmentally severe than with gasoline. Because ethanol contains oxygen, using it as a fuel additive results in lower carbon monoxide emissions. The E10 blend results in 12 to 25 percent less carbon monoxide emissions than conventional gasoline. E10 is widely used in areas that fail to meet the EPA's air quality standards for carbon monoxide. However, some research indicates that under common driving conditions E10 can increase **ozone** concentrations. Breathing ozone in unhealthy concentrations can result in damage to the lungs and cause coughing and shortness of breath. In contrast to E10, E85 reduces ozone-forming volatile organic compounds and carbon monoxide.

Compared to gasoline, the production and use of corn ethanol could result in little to no carbon dioxide (CO₂) reductions in the near future. This is because an increased demand for ethanol may lead to converting forests and grasslands to crop land for fuel and food. This conversion releases carbon dioxide into the atmosphere. When these factors are taken into account, switching to corn ethanol from gasoline would provide little or no climate change benefit in the next 50 years. However, the production and use of cellulosic ethanol could reduce CO₂ emissions by 18 to 25 percent compared to gasoline, even when the impacts from clearing land for crops are considered.

Land Use and Ethanol

One concern with the use of corn ethanol is that the land required to grow the corn might compete with land needed to grow food. If this is true, the increased demand for corn could cause food prices to rise. Poultry farmers and ranchers are concerned that the cost of feed for their animals would rise. A global spike in food prices in 2008 was partially caused by increased demand for ethanol. Though it was only a small component of the price spike, the 2008 experience has caused concern that greatly increasing the use of corn ethanol could affect food prices more significantly.

A study by the Department of Energy and the Department of Agriculture concluded that by 2030 it would be possible to replace 30 percent of our gasoline use with ethanol without increasing demands on crop land. While we can't sustainably meet all of our transportation fuel needs with ethanol, increased ethanol use in the future could significantly decrease our dependence on petroleum.



Biofuels: Biodiesel

What Is Biodiesel?

Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, animal fats, or greases, such as recycled restaurant grease. Most biodiesel today is made from soybean oil. Biodiesel is most often blended with petroleum diesel in ratios of two percent (B2), five percent (B5), or 20 percent (B20). It can also be used as neat (pure) biodiesel (B100). Biodiesel fuels are compatible with and can be used in unmodified diesel engines with the existing fueling infrastructure. It is one of the fastest growing transportation fuels in the U.S.

Biodiesel contains virtually no sulfur, so it can reduce sulfur levels in the nation's diesel fuel supply, even compared with today's low-sulfur fuels. While removing sulfur from petroleum-based diesel results in poor lubrication, biodiesel is a superior lubricant and can reduce the friction of diesel fuel in blends of only one or two percent. This is an important characteristic because the Environmental Protection Agency now requires that sulfur levels in diesel fuel be 97 percent lower than they were prior to 2006.

Characteristics of Biodiesel

Biodiesel exceeds diesel in cetane number, resulting in superior ignition. The cetane number is the performance rating of diesel fuel. Biodiesel also has a higher flash point, or ignition temperature, making it safer. Horsepower, acceleration, and torque are comparable to diesel. Biodiesel has the highest Btu content of any alternative fuel, though it is slightly less than that of petroleum-based diesel. This might have a small impact on vehicle range and fuel economy.

Distribution of Biodiesel

Biodiesel is available throughout the United States, mainly through commercial fuel distributors. Even though the number of biodiesel fueling stations is still relatively low compared to the number carrying petroleum-based diesel, the availability of biodiesel is growing. Most B20 or higher fueling stations are located in Illinois, Iowa, Minnesota, Arkansas, California, and Oregon.

Economics of Biodiesel

Today, B99-B100 costs about \$4.57 a gallon, but costs can vary depending on region, the base crop, purchase volume, and delivery costs. Historically, all biodiesel blends cost more than diesel. In 2005, a Biodiesel Excise Tax Credit went into effect, but this credit has expired, eliminating some incentives for biodiesel use.

Because it is stored in existing infrastructure and can fuel vehicles without modification, biodiesel has emerged as a popular fuel for fleets regulated by the Energy Policy Act (EPACT). The cost difference between biodiesel fuel for the public and for fleet vehicles will likely decrease in the future due to production improvements in

BIODIESEL-POWERED GARBAGE TRUCK



Image courtesy of NREL

Any vehicle that operates on diesel fuel can switch to B100 or a biodiesel blend without changes to its engine. Many state fleets and school districts have switched from diesel to biodiesel blends to reduce emissions and improve air quality.

BIODIESEL FUELING STATION



Photo courtesy of Elly Jonez via wikimedia commons

the biodiesel industry. In addition, many states are considering legislation that will encourage greater use of biodiesel fuels to improve air quality.

Another economic consideration is the agriculture industry. The expanded use of biodiesel in the nation's fleets will require the agriculture industry to substantially increase production of soybeans and other oilseed crops that can be used as **feedstocks** for biodiesel. Farmers will have new crops and markets to support economic stability.

Environmental Impacts

Biodiesel is renewable, nontoxic, and biodegradable. Compared to diesel, biodiesel (B100) reduces sulfur oxide **emissions** by 100 percent, particulates by 48 percent, carbon monoxide by 47 percent, unburned hydrocarbons by 67 percent, and hydrocarbons by 68 percent. However, biodiesel increases emission of nitrogen oxides slightly (10 percent). Biodiesel blends generally reduce emissions in proportion to the percentage of biodiesel in the blend.

Like other transportation fuels, when biodiesel is burned it releases CO₂. CO₂ is a major contributor to climate change; however, biodiesel is made from crops that absorb carbon dioxide and give off oxygen. This cycle would maintain the balance of CO₂ in the atmosphere, but because of the CO₂ emissions from farm equipment and production of fertilizer and pesticides, biodiesel adds more CO₂ to the atmosphere than it removes.

Compared to diesel, the production and use of soybean biodiesel could result in little to no CO₂ reductions in the near future. This is because an increased demand for biodiesel may lead to converting forests and grasslands to crop land for fuel and food. This conversion releases carbon dioxide into the atmosphere. When these factors are taken into account, switching to soy biodiesel from petroleum diesel would provide little or no climate change benefit in the next 50 years. By comparison, the production of and use of biodiesel from recycled waste oils compared to petroleum diesel could reduce CO₂ emissions by over 80 percent.

Land Use and Biodiesel

One concern with the use of biodiesel is that the land required to grow the increased amount of soybeans might compete with land needed to grow food. If this is true, the increased demand for soybeans could cause food prices to rise. A study by the Department of Energy and the Department of Agriculture concluded that by 2030 it would be possible to replace 30 percent of our gasoline and diesel use with biofuels without increasing demands on cropland. This would be accomplished by using mostly agricultural and forestry waste and perennial crops grown on marginal lands.

Biodiesel is a domestic, renewable fuel that can improve air quality. The expanded use of biodiesel by fleets, as well as individual consumers, has the potential to reduce the importation of foreign oil and promote national security.

WASTE OIL



Photo courtesy of Joe Mabel via wikimedia commons

SOYBEAN FIELD

