# 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

We use several types of biomass today, including wood, agricultural products, solid waste, landfill gas and biogas, and biofuels. The uses for alcohol fuels, like ethanol, will be discussed in depth in the coming pages.

### ▪ Wood

Most biomass used today is home grown energy. Wood—logs, chips, bark, and sawdust—accounts for about 45 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources can include agricultural waste products like fruit pits and corncobs.

Wood and wood waste are used to generate electricity. Much of the electricity is used by the industries making the waste; it is not distributed by utilities, it is cogenerated. 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 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 to meet 63 percent of their energy needs. Other industries that use biomass 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 much 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 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.

## Biomass at a Glance, 2011

**Classification:**
- renewable

**Major Uses:**
- electricity, transportation fuel, heating

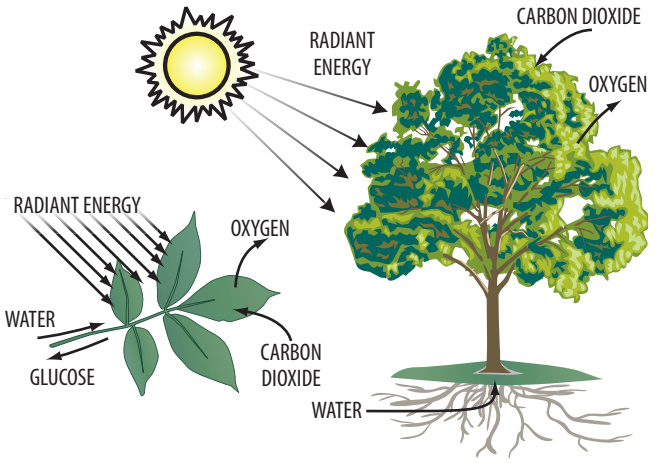
**U.S. Energy Consumption:**
- 4.411 Q
- 4.54%

**U.S. Energy Production:**
- 4.511 Q
- 5.78%

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

## Photosynthesis

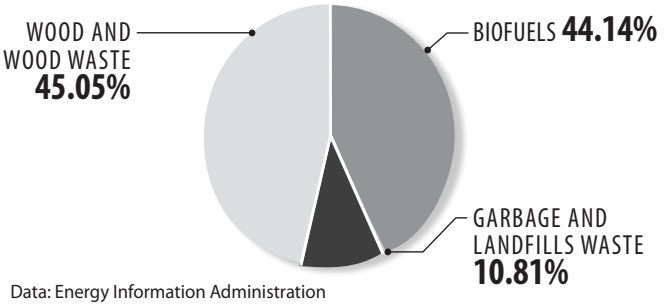
In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose (or sugar).




**water + carbon dioxide + sunlight → glucose + oxygen**

$6\ H_2O + 6\ CO_2 + \text{radiant energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$

## U.S. Sources of Biomass, 2011




Data: Energy Information Administration

### ▪ 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.

Methane, the main ingredient in natural gas, is a good energy source. Most gas furnaces and stoves 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 about 9,000 Kentucky homes.

Today, 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 rarely economical to collect. Methane, however, is a more powerful greenhouse gas than carbon dioxide. It is better 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 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. They need moderate temperatures and moisture for the fermentation process to occur. For developing countries, biogas digesters may 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 over-used 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. Today, biomass provides 4.54 percent of the total energy we consume. Biomass has largely been replaced by coal, natural gas, and petroleum.

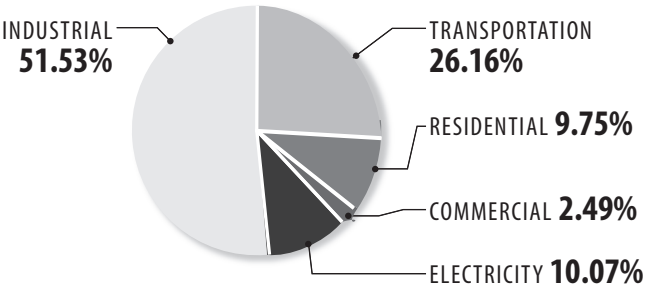
Almost half of the biomass used today comes from burning wood and wood scraps such as saw dust. More than 44 percent is from **biofuels**, principally ethanol, that are used as a gasoline additive. The rest comes from crops, garbage, and landfill gas.

Industry is the biggest user of biomass. Almost 52 percent of biomass is used by industry. Electric utilities use 10 percent of biomass for power generation. Biomass produces 1.38 percent of the electricity we use.

Transportation is the next biggest user of biomass; over 26 percent of biomass is used by the transportation sector to produce biofuels like ethanol and biodiesel, (see pages 14-15).

The residential sector uses almost 10 percent of the biomass supply. About one-tenth of American homes burn wood for heating, but few use wood as the only source of heat. Most of these homes burn wood in fireplaces and wood stoves for additional heat.

### U.S. Biomass Consumption by Sector, 2011




Data: Energy Information Administration

## Using Biomass Energy

Usually we burn wood and use its energy for heating. Burning, however, is not the only way to convert biomass energy into a usable energy source. There are four 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.

**Burning:** 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.

**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. Many landfills are recovering and using 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 liquid form of methane.

## 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. Growing plants for use as biomass fuels may also help keep carbon dioxide levels balanced. Plants remove carbon dioxide—one of the **greenhouse gases**—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 10 percent ethanol and is known as E10. In 2011, the U.S. Environmental Protection Agency 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. There are almost nine million flexible fuel vehicles (FFV) on the road that can run efficiently on E85. However, only seven percent of these vehicles 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 cruise speed to those using gasoline. However, because ethanol contains less energy per gallon than gasoline, vehicle range (the distance a vehicle can travel on a tank of fuel) can be 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

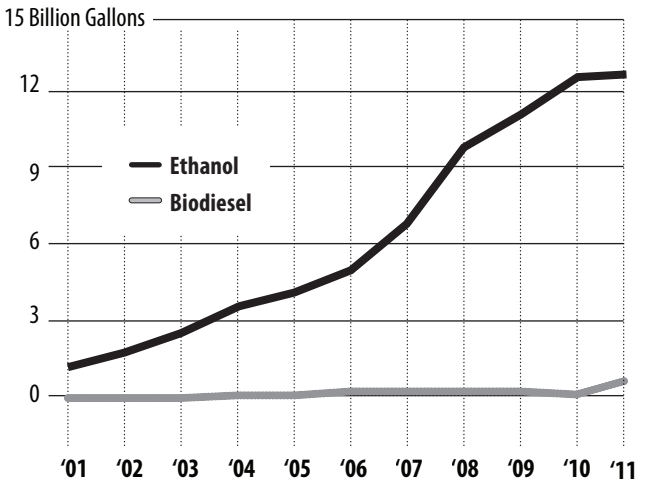
In 2011, ethanol plants in the U.S. produced almost 14 billion gallons of ethanol. There are over 190 plants operating nationwide. These plants are located mostly in the Midwest. Many new plants are in the planning stages. There are currently more than 2,500 E85 fueling stations in 47 states. Ethanol 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 already exceeding this mark, producing over 12 billion gallons of ethanol alone in 2010 and 2011. For comparison, the U.S. consumed 120 billion gallons of gasoline in 2011. Today, it costs more to produce ethanol than gasoline, however, federal and state tax advantages make ethanol competitive in the marketplace.

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.

### U.S. Consumption of Biofuels, 2001-2011




## 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 ($CO_2$) 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. By comparison, the production and use of cellulosic ethanol could reduce $CO_2$ 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 it 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, in the future it 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 alternative 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 (performance rating of diesel fuel), resulting in superior ignition. Biodiesel has a higher flashpoint, making it more versatile where safety is concerned. 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 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. Currently there are relatively few public pumps that offer biodiesel; it is a more practical fuel for fleets with their own fueling facilities. Availability for consumers is steadily expanding as demand grows.

## Economics of Biodiesel

Today, B99-B100 costs between $3.77 and $5.67 a gallon, depending on region, the base crop, purchase volume, and delivery costs. Historically, all biodiesel blends cost more than diesel. In 2005, the Biodiesel Excise Tax Credit went into effect. Blenders of biodiesel receive tax credits for the biodiesel they blend with diesel, allowing them to make biodiesel fuel available at a lower cost. This incentive expires at the end of 2013.

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

**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 are switching from diesel to biodiesel blends to reduce emissions and improve air quality.**

## 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. Emissions of nitrogen oxides, however, increase slightly (10 percent). Biodiesel blends generally reduce emissions in proportion to the percentage of biodiesel in the blend.

When biodiesel is burned it releases carbon dioxide ($CO_2$), which 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 $CO_2$ in the atmosphere, but because of the $CO_2$ emissions from farm equipment and production of fertilizer and pesticides, biodiesel adds more $CO_2$ to the atmosphere than it removes.

Compared to diesel, the production and use of soybean biodiesel could result in little to no $CO_2$ 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 could reduce $CO_2$ emissions by over 80 percent compared to petroleum diesel.

## 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.