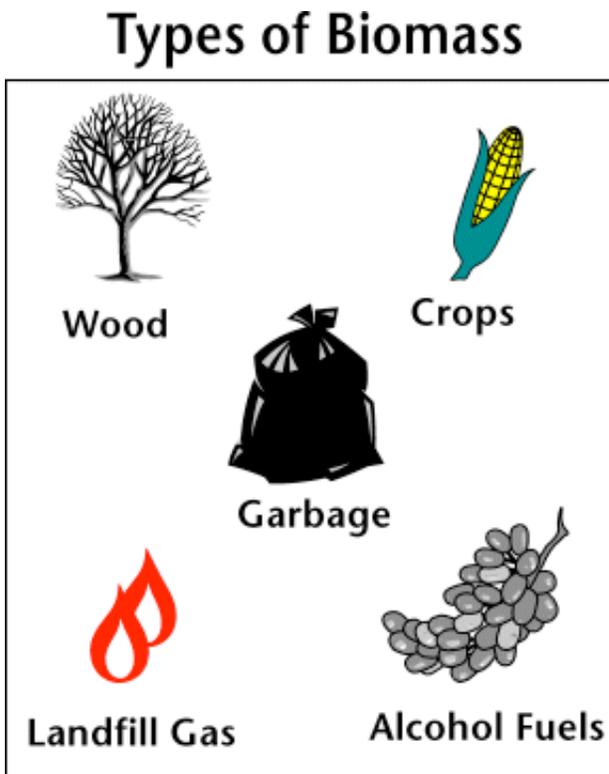


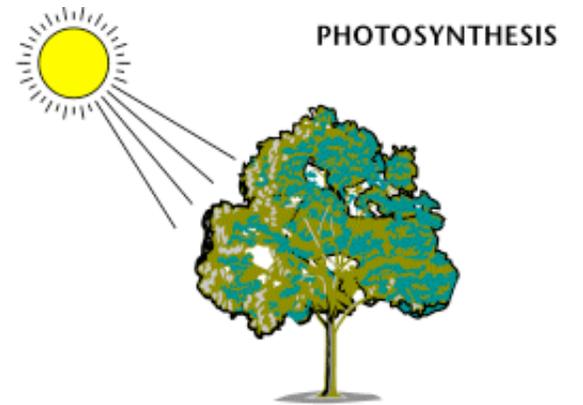
Renewable Biomass

Biomass Basics

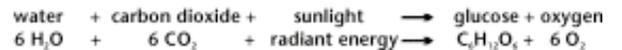
Biomass – Renewable Energy from Plants and Animals



Source: The National Energy Education Project (Public Domain)



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



Source: The National Energy Education Project (Public Domain)

Biomass is organic material made from plants and animals (microorganisms). Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. The chemical energy in plants gets passed on to animals and people that eat them.

Biomass is a renewable energy source because we can always grow more trees and crops, and waste will always exist. Some examples of biomass fuels are wood, crops, manure, and some garbage.

When burned, the chemical energy in biomass is released as heat. If you have a fireplace, the wood you burn in it is a biomass fuel. Wood waste or garbage can be burned to produce steam for making electricity, or to provide heat to industries and homes.

Converting Biomass to Other Forms of Energy

Burning biomass is not the only way to release its energy. Biomass can be converted to other useable forms of energy, such as methane gas or transportation fuels, such as ethanol and biodiesel.

Methane gas is the main ingredient of natural gas. Smelly stuff, like rotting garbage, and agricultural and human waste, release methane gas — also called "landfill gas" or "biogas."

Crops like corn and sugar cane can be fermented to produce ethanol. Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats.

How Much Biomass Is Used for Fuel?

Biomass fuels provided about 4% of the energy used in the United States in 2011. Of this, about 45% was from wood and wood-derived biomass, 44% from biofuels (mainly ethanol), and about 11% from municipal waste. Researchers are trying to develop ways to burn more biomass and less fossil fuels. Using biomass for energy may cut back on waste and greenhouse gas emissions.

Wood & Wood Waste

Burning Wood Is Nothing New

The most common form of biomass is wood. For thousands of years people have

burned wood for heating and cooking. Wood was the main source of energy in the United States and the rest of the world until the mid-1800s. Wood continues to be a major source of energy in much of the developing world.

In the United States, wood and wood waste (bark, sawdust, wood chips, wood scrap, and paper mill residues) provide about 2% of the energy we use today.

Using Wood and Wood Waste

About 80% of the wood and wood waste fuel used in the United States is consumed by industry, electric power producers, and commercial businesses. The rest, mainly wood, is used in homes for heating and cooking.

Many manufacturing plants in the wood and paper products industry use wood waste to produce their own steam and electricity. This saves these companies money because they don't have to dispose of their waste products and they don't have to buy as much electricity.

Waste-To-Energy

Energy from Garbage

Garbage, often called municipal solid waste (MSW), is the source of about 6% of the total biomass energy consumed in the United States. MSW contains biomass (or biogenic) materials like paper, cardboard, food scraps, grass clippings, leaves, wood, and leather products, and other non-biomass combustible materials, mainly plastics and other synthetic materials made from petroleum.

Americans produce more and more waste each year. In 1960, the average American threw away 2.7 pounds of trash a day. Today, each American throws away about 4.4

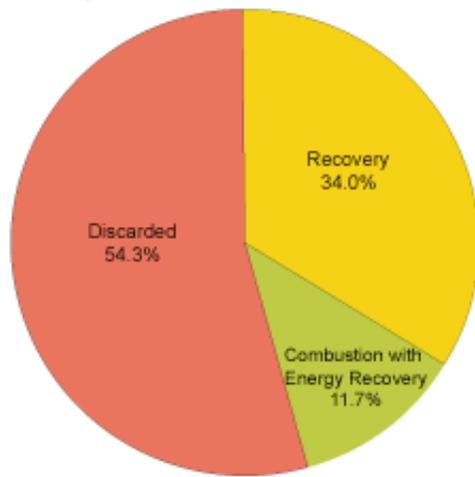
Hybrid Poplar Wood Chips Being Unloaded in Crookston, Minnesota



Source: National Renewable Energy Laboratory, U.S. Department of Energy (Public Domain)

pounds of trash every day. Of that, about 1.5 pounds are recycled or composted. What do we do with the rest? One option is to burn it. (Burning is

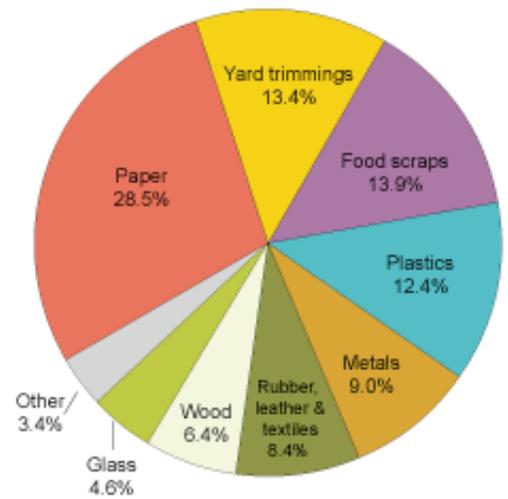
Management of MSW in the United States, 2010



Source: U.S. Environmental Protection Agency, *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2010* (November 2010).

Total MSW Generation (by material), 2010

250 Million Tons (before recycling)



Source: U.S. Environmental Protection Agency, *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2010* (November 2010).

sometimes called combustion.) About 85% of our household trash is material that will burn, and most of that is biogenic, or material that is made from biomass (plant or animal products). About 62% of MSW (by weight) is biogenic.

Waste-to-Energy Plants Make Steam and Electricity

Today, we can burn MSW in special waste-to-energy plants and use its heat energy to make steam to heat buildings or to generate electricity. There are about 87 waste-to-energy plants in the United States that generate electricity or produce steam. In 2010, these plants burned about 12% of MSW and generated 14 million kilowatt hours of electricity, about the same amount used by 1.2 million U.S. households. The biogenic material in MSW contributes about 55% of the energy when MSW is burned in waste-to-energy facilities. Many large landfills also generate electricity with the methane gas that is produced as biomass decomposes in the landfills.

Waste-to-Energy Plants Also Dispose of Waste

Providing electricity is not the major advantage of waste-to-energy plants. It actually costs more to generate electricity at a waste-to-energy plant than it does at a coal, nuclear, or hydropower plant.

The major advantage of burning waste is that it reduces the amount of material that we bury in landfills. Waste-to-energy plants burned about 29 million tons of MSW in 2010. Burning MSW reduces the volume of waste by about 87%.

Biogas

Collecting Gas from Landfills

Landfills can be a source of energy. Anaerobic bacteria that live in landfills decompose organic waste to produce a gas called biogas that contains methane.

Methane is the same energy-rich gas that is in natural gas, which is the fuel used for heating, cooking, and producing electricity. Methane is colorless and odorless, and a very strong greenhouse gas. Natural gas utilities add an odorant (bad smell) so people can detect natural gas leaks from pipelines. Landfill biogas can also be dangerous to people or the environment. New rules require landfills to collect methane gas for safety and pollution control.

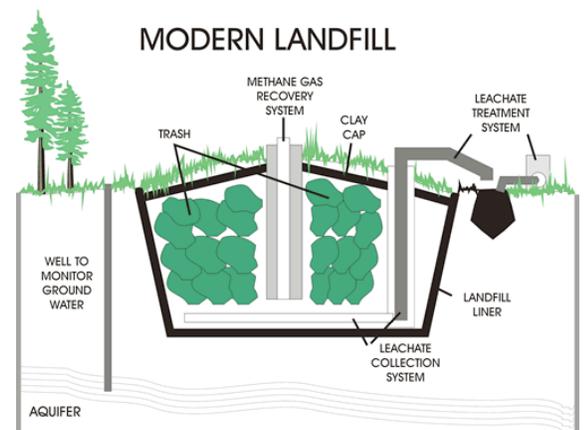
Some landfills simply burn the methane gas in a controlled way to get rid of it. But the methane can also be used as an energy source. Landfills can collect the methane gas, treat it, and then sell it as a commercial fuel. It can then be burned to generate steam and electricity.

Landfill Gas Energy Projects

As of October 2011, 526 landfills have 563 operating gas to energy projects in the United States. California has the most landfill gas energy projects in operation (76), followed by Pennsylvania (39), and Michigan (36).

Using Animal Waste

Some farmers produce biogas in large tanks called "digesters" where they put manure



Source: The National Energy Education Project (Public Domain)

and bedding material from their barns. Some cover their manure ponds (also called lagoons) to capture biogas. Biogas digesters and manure ponds contain the same anaerobic bacteria in landfills. The biogas can be used to generate electricity or heat for use on the farm, or to sell electricity to an electric utility.

Read about a [field trip](#) to a real waste-to-energy plant or learn about the history of MSW.

Biomass & the Environment

Using Biomass for Energy Can Have Positive and Negative Impacts

Using biomass for energy can have both positive and negative impacts on the environment. For example, burning biomass may result in more or less air pollution depending on the type of biomass and the types of fuels or energy sources that it replaces. Biomass like lumber mill sawdust, paper mill sludge, yard waste in household trash used for energy may avoid the use of fossil fuels such as coal or natural gas. Burning fossil fuels and biomass releases [carbon dioxide](#) (CO₂), a [greenhouse gas](#), but when the plants that are the sources of biomass are grown, a nearly equivalent amount of CO₂ is captured through photosynthesis. Sustainable cultivation and harvesting of biomass can result in no net increase in CO₂ emissions. Each of the different forms and uses of biomass impact the environment in a different way.

Burning Wood

Using wood, and charcoal made from wood, for heating and cooking can replace fossil fuels and may result in lower CO₂ emissions. Wood may be harvested from forests or woodlots that have to be thinned or come from urban trees that fall down or have to be cut down anyway. However, wood smoke contains harmful pollutants like carbon monoxide and particulate matter. Burning wood in an open fireplace is very

Panicum Virgatum (Switchgrass) Being Grown

inefficient and produces lots of air pollution. Modern wood stoves and fireplace inserts are designed to release small amounts of particulates. Fireplace inserts are like wood stoves that fit into a fireplace. Wood and charcoal are major cooking and heating fuels in poor countries, and the wood may be harvested faster than trees can grow. This results in deforestation. Planting fast-growing trees for fuel and using fuel-efficient cooking stoves can help slow deforestation and improve the environment.



Source: [Wikimedia Commons](#)
(Public Domain)

Burning Municipal Solid Waste (MSW) or Wood Waste

Burning municipal solid waste (MSW, or garbage) and wood waste to produce energy means that less of it has to get buried in landfills. Like plants that burn coal, waste-to-energy plants produce air pollution when the fuel is burned to produce steam or electricity. Burning garbage releases the chemicals and substances found in the waste. Some of these chemicals can be dangerous to people, the environment, or both, if they are not properly controlled.

Incinerators and waste-to-energy power plants must use technology to prevent harmful gases and particles from coming out of their smoke stacks. The Environmental Protection Agency (EPA) applies [strict environmental rules to waste-to-energy plants](#). The EPA requires waste-to-energy plants to use anti-pollution devices, including scrubbers, fabric filters, and electrostatic precipitators to capture air pollutants.

Plants that burn waste to make electricity must use technology to prevent harmful gases and particles from coming out of their smoke stacks.

The EPA wants to ensure that harmful gases and particles don't go out the smokestack into the air. Scrubbers clean chemical gas emissions by spraying a liquid into the gas

stream to neutralize the acids. Fabric filters and electrostatic precipitators remove particles from the combustion gases. The particles — called fly-ash — are then mixed with the ash that is removed from the bottom of the waste-to-energy plant's furnace.

A waste-to-energy furnace burns at such high temperatures (1,800 to 2,000°F) that many complex chemicals naturally break down into simpler, less harmful compounds. This chemical change is a kind of built-in anti-pollution device.

Disposing of Ash from Waste-to-Energy Plants

Another challenge is the disposal of the ash after combustion. Ash can contain high concentrations of various metals that were present in the original waste. Textile dyes, printing inks, and ceramics, for example, contain the metals lead and cadmium.

Separating waste before combustion can solve part of the problem. Because batteries are the largest source of lead and cadmium in municipal waste, they should not be put into regular trash. Florescent light bulbs should also not be put in trash because they contain small amounts of mercury.

The EPA tests ash from waste-to-energy plants to make sure it's not hazardous. The test looks for chemicals and metals that would contaminate ground water by trickling through a landfill. Ash that is considered safe is used in municipal solid waste landfills as a daily or final cover layer, to build roads, to make cement blocks, and even to make artificial reefs for marine animals.

About one-third of all the ash produced is used in landfills as a daily or final cover layer, to build roads, to make cement blocks, and even to make artificial reefs for marine animals.

Collecting Landfill Gas or Biogas

Biogas is a gas composed mainly of methane and carbon dioxide that forms as a result of biological processes in sewage treatment plants, waste landfills, and livestock manure management systems. Methane is one of the greenhouse gases associated with global climate change.¹ Many of these facilities capture and burn the biogas for

heat or electricity generation. Burning methane is actually beneficial because methane is a stronger greenhouse gas than CO₂. The electricity generated from biogas is considered "green power" in many States and may be used to meet State renewable portfolio standards (RPS). The electricity may replace electricity produced by burning fossil fuels and result in a net reduction in CO₂ emissions.

Liquid Biofuels: Ethanol and Biodiesel

Ethanol and biodiesel were the fuels used in the first automobile and diesel engines, but lower cost gasoline and diesel fuel made from crude oil became the dominant vehicle fuels. The federal government has promoted ethanol use in vehicles to help reduce oil imports since the mid-1970s. In 2007, the government set a target for biofuels use of 36 billion gallons by the year 2022. As a result, nearly all gasoline now sold in the United States contains some ethanol.

Biofuels may be considered to be carbon-neutral because the plants that are used to make biofuels (such as corn and sugarcane for ethanol, and soy beans and palm oil trees for biodiesel) absorb CO₂ as they grow and may offset the CO₂ produced when biofuels are made and burned.

Growing plants for biofuels is controversial however, as the land, fertilizers, and energy used to grow biofuel crops could be used to grow food crops instead. Also, in some parts of the world, large areas of natural vegetation and forests have been cut down to grow sugar cane for ethanol and soybeans and palm-oil trees to make biodiesel. The U.S. government is supporting efforts to develop alternative sources of biomass that do not compete with food crops and use less fertilizer and pesticides than corn and sugar cane, and methods to produce ethanol that require much less energy than conventional fermentation. Ethanol may also be made from waste paper, and biodiesel can be made from waste grease and oils and even algae.

Ethanol and ethanol-gasoline mixtures burn cleaner and have higher octane than pure gasoline, but have higher "evaporative emissions" from fuel tanks and dispensing equipment. These evaporative emissions contribute to the formation of harmful, ground-level ozone and smog. Gasoline requires extra processing to reduce

evaporative emissions before it is blended with ethanol. Compared to petroleum diesel, biodiesel combustion produces less sulfur oxides, particulate matter, carbon monoxide, and unburned and other hydrocarbons, but more nitrogen oxide.

1. U.S. Environmental Protection Agency, [Climate Change State of Knowledge](#).