

Facts about Biomass Fuels

Introduction

Throughout history humans have used fuels made from plant and animal matter for heating and cooking. Today, technological advances and society's increasing demand for energy have led to an expanded role for these biomass fuels. Biomass is plant or animal matter. The raw materials for biomass include dedicated energy resources such as trees, crops, grasses, and algae. Various waste streams such as agricultural waste, human and animal waste, forest product and paper mill waste, and municipal solid waste can also be collected as biomass sources. Furthermore, biomass sources can be used to produce higher value biomass fuels in the form of solids (e.g., wood pellets), liquids (e.g., ethanol), or gases (e.g., methane).

Biomass gets its energy from the sun. Photosynthesis converts solar energy striking the leaves of plants into chemical energy, which is stored in the plants themselves in the form of sugars, starches, oils, cellulose and lignin. Animals that eat plants store some of this energy in their bodies in the form of fat; some of it is also excreted in manure and other wastes. Biomass fuels are renewable, because the raw materials used to make the fuels can be replaced within a human lifetime simply by growing more crops or collecting more waste.

In the English system of measurement, the energy content of biomass fuels is usually measured in Btu (British thermal units). The energy produced by a lit match is roughly equal to one Btu. The Btu is commonly used in the United States, however scientists, engineers, and most international countries prefer to measure energy using the metric unit of measure, the Joule (J).

Types of Biomass Sources (Raw Materials)

Wood

Wood is by far one of the oldest and most abundant types of biomass feedstocks. Wood was once the main energy resource used during the early history of the United States, but now it plays only a small role in meeting the nation's energy needs (3%). Still, in certain parts of the country, including Wisconsin, wood provides people with an inexpensive and plentiful source of energy for heating. About 20 percent of U.S. homes get some heat from burning wood, while about four percent use it as their primary fuel. In addition to cord wood, other types of forest products residues such as tree tops, branches, bark, logging slash, and saw mill waste can be used as sources of biomass energy (See [Facts About Wood](#)).

Energy Crops

Many crops that have been traditionally raised for food can also serve as a source of biomass energy. The most dominant examples in use today include corn, sugar cane, soy, and canola. In many cases, a portion of the crop can be used for energy (for example soy oil) while the other portion can be used for food consumption (for example soy meal). Many types of energy crops can be raised on marginal farmlands that are not capable of supporting high yield food crops on an economically competitive basis.

Algae

Aquatic algae are capable of photosynthesis, and many species demonstrate incredible growth rates compared to land based plants. Because they are aquatic, algal growth is not limited by the availability of water.



Facts about Biomass Fuels

Furthermore, because these organisms are suspended in the water column, they do not need to expend energy in the creation of cellulosic structural materials to support them and counteract the force of gravity. As a result, algae are able to store a lot more of their energy in the form of sugars, starches, or oils. In fact, the composition of some algal species can be over 50% stored oil as a percentage of their body mass. Although algae have enormous potential as a biomass source due to their rapid growth rates, there are numerous challenges that must be addressed to make them economical for biomass energy applications. These include issues of cultivation, harvesting, de-watering, drying, and extraction of oil or carbohydrate feedstocks.

Agricultural Wastes

Agricultural wastes are plant parts left over after farmers have harvested their crops. These wastes include stalks, husks, prunings, straw, and corn cobs. Agricultural waste may also include crops that were lost due to diseases or pests, and crops that spoiled in the field before they could be harvested. Agricultural wastes can be collected, dried, and burned to produce energy. Burning agricultural wastes in small power plants can provide a convenient source of energy for rural areas and developing countries. The ash that remains from burning agricultural wastes can be used as fertilizer or added to compost, as it contains minerals such as potassium and phosphorus.

Agricultural wastes are used to produce energy in many parts of the world. In Hawaii and Brazil, bagasse, a residue left over after sugarcane is harvested and processed, is burned in power plants to produce electricity. In Denmark, straw is burned to produce heat for farms, and in some parts of rural Wisconsin corn and corn stover (leftover corn cobs, leaves, and stalks) are sometimes burned for space heat. An analysis by the USDA Billion Ton Study found that in 2016 Wisconsin had the potential to produce 2.8 million dry tons of agricultural waste, primarily in the form of corn stover. Under various growth scenarios modeled by the USDA, this resource could grow to over 8 million dry tons of agriculture waste by 2040, which could be used to produce over billion gallons of ethanol per year for transportation fuel (See Liquid Alcohol Fuels below).

Human and Animal Wastes

Animal waste products such as manure have long provided biomass fuel for rural societies. In developing countries throughout Asia and Africa, animal manure is collected and dried into cakes that can be stacked, stored, traded and sold for as a source of solid fuel for heating and cooking. On a larger scale, some plants in the U.S. generate electricity by drying and burning manure from farms and cattle feedlots. One plant in Benson, Minnesota burns turkey manure and produces enough power for 40,000 homes.

Instead of drying and burning manure, it can also be placed into enclosed airtight tanks called anaerobic digesters, where it is broken down by bacteria and various chemical processes to produce biogas (60 percent methane and 40 percent carbon dioxide). In developing countries, small-scale production of biogas can provide fuel for cooking, while in industrialized countries large-scale production of biogas can generate electricity or provide heat for manufacturing processes.

Biogas-fueled electric power plants are becoming increasingly common throughout the world. Over 200 farms in the U.S. have installed biogas recovery systems that use cattle and hog manure to produce electricity. Wisconsin currently leads the U.S. with over 30 operating manure digester biogas electrical generator systems, and many more Wisconsin dairy farms have the potential to produce biogas from manure.

The same anaerobic digestion process can be conducted at waste water treatment facilities to generate biogas energy from human sewage. The biogas can be used to heat water treatment tanks which break down waste and kill pathogens in the waste. The benefits of this technique include odor control, waste reduction, and reducing the energy costs required to operate the treatment plant.

Facts about Biomass Fuels

McCain Foods in several locations around Wisconsin has employed an energy efficiency and renewable energy initiative, including a wastewater treatment facility on site at the Plover location that converts waste into energy. McCain Foods save approximately \$875,000 per year in electric bills, partly due to this waste-to-energy system. Likewise, the sewage treatment plant in Madison, Wisconsin offsets about 35 percent of its energy consumption through the use of biogas.

Municipal Solid Waste (MSW)

Waste disposed of by residents and businesses, called municipal solid waste (MSW), can provide a source of fuel. A large percentage of this waste is made up of organic materials such as wood, paper products, food waste, and yard waste. Therefore, some MSW is a form of biomass fuel.

Specially equipped waste-to-energy power plants can use MSW to produce electricity or heat. The waste is separated and non-combustible materials are removed before the remaining waste is taken to the power plant to be burned. At the end of 2015, 71 waste-to-energy facilities existed in the United States. Mostly located in the Northeast and Florida, these plants have a total of 2.3 gigawatts per year capacity and can process more than 26 million tons of waste per year.

Another source of fuel from MSW is landfill gas. This gas is produced by the breakdown of organic material. Landfill gas, which contains a mixture of methane, carbon dioxide and other trace gases can be burned to generate electricity. In Southeastern Wisconsin landfills producing electricity have been in operation for more than 30 years.

Types of Value Added Biomass Fuels

Solid Biomass Pellets

Pellets are made from biomass feedstocks that are dried, pulverized, and compressed. Pellets can be made from several types of biomass including industrial wood waste, food waste, agricultural residues, energy crops, and virgin lumber. Wood pellets are the most common type of pellet fuel and are generally made from compacted sawdust and wastes from the milling of lumber, manufacture of wood products, and construction debris. Pellets can be used as fuels for power generation in a centralized plant, and for commercial or residential space heating. The compression process makes pellets extremely dense and also results in a low moisture content (below 10%). These factors provide a higher combustion efficiency and lower airborne emissions than ordinary cordwood.

Liquid Alcohol Fuels

Biomass feedstocks can be used to produce various types of alcohol fuels such as methanol (wood alcohol), ethanol (grain alcohol), and butanol that can serve as replacements for gasoline. While all of these alcohol fuels can be used in motor vehicles, ethanol is by far the most common alcohol fuel produced in the U.S. Ethanol is created by extracting carbohydrates (sugars and starches) from crops such as corn, sugar beets, or grasses, and fermenting them with yeast. The resulting alcoholic mixture is then distilled to purify the ethanol fuel.

The United States produced over 15 billion gallons of ethanol in 2016. Midwestern states produce most of the U.S. ethanol, because these states grow large amounts of corn and sorghum, the primary feedstocks for ethanol production. Wisconsin produces more than 540 million gallons of ethanol each year, and ranked eighth in the nation for ethanol production capacity in 2017. Analysts estimate potential ethanol production in Wisconsin to be over 900 million gallons annually—enough to meet a large portion of the state's transportation needs. Wisconsin's first ethanol plants were built in 2002, and there are now over 75 operating ethanol plants in Wisconsin, Illinois, Iowa, and Minnesota. These plants operate using a variety of feedstocks including corn, sorghum, sugar beets, cheese whey, corn stover, switchgrass, potato starch waste and paper waste.

Facts about Biomass Fuels

Gasoline mixed with 10 percent ethanol (sometimes called gasohol), is labeled at the pump as E10 and was first introduced for sale to consumers in the Midwest. Over the past decade, E10 has been promoted by the Environmental Protection Agency to help reduce tailpipe emissions from petroleum fuels, and E10 is now sold at most service stations throughout the United States. All vehicles, motors, and equipment produced today can run on E10 fuel. Flex fuel vehicles are designed to operate on fuel mixtures with even higher concentrations of ethanol. Gasoline mixed with 85 percent ethanol is labeled at the pump as E85, and flex fuel vehicles can run on E85, E10, pure gasoline, or any combination thereof.

Liquid BioDiesel Fuel

Biomass feedstocks can also be used to produce various types of fuels that can serve as replacements for petroleum based diesel fuel. The most common group of these are fatty acid methyl esters (FAMES) are sold in the marketplace as BioDiesel fuel. BioDiesel is created by extracting oils from crops such as soy, canola, or sunflower, or collecting fats such as pork lard or beef tallow from animal rendering processes. The fats and oils are then reacted with methyl alcohol and a strong base catalyst to produce BioDiesel fuel.

The U.S. produced over 1.5 billion gallons of biodiesel in 2016. Wisconsin's largest biodiesel production facility is operated by Renewable Energy Group Inc. It is located in DeForest, Wisconsin, and has the capacity to produce 25 million gallons per year.

Blends of BioDiesel mixed with Petroleum diesel are now commonly sold at the pump throughout the Midwest, with the most common blends being 5, 10, and 20% biodiesel (sold as B5, B10, and B20). Almost all diesel fueled vehicles, motors, and equipment produced today can run on BioDiesel blends up to B20. Some manufacturers also make equipment designed to run on pure biodiesel fuel, or B100. This is most common for off road agriculture equipment used by farmers.

BioMethane / Bio Compressed Natural Gas (Bio CNG)

Raw biogas produced by an anaerobic digester or a landfill can be cleaned and upgraded to improve its utility as a fuel. In addition to methane, raw biogas typically contains carbon dioxide, water vapor, and several other trace gases. The carbon dioxide and water vapor limit the energy content of raw biogas to about 500 Btu/ft³, while the various trace gases such as siloxanes and hydrogen sulfide can adversely affect engine equipment. To produce BioMethane (also known as Bio CNG), the raw biogas is sent through various scrubber units to remove the undesirable components. The scrubbing process increases the energy density of the gas, resulting in a finished product with an energy density of 1000 Btu/ft³, which is equivalent to pipeline natural gas. Once cleaned, the BioMethane can then be injected into an ordinary natural gas pipeline for delivery to customers, or it can be used to fuel natural gas powered vehicles.

In Wisconsin, the Dane County Landfill operates a BioMethane system for fueling Dane County public works and trash collection vehicles. The system produces 250 gallons of gasoline equivalent of BioMethane each day from the landfill gas that is captured, cleaned, and compressed for use as vehicle fuel. Because of the success of the BioMethane system, Dane County now buys much less gasoline and diesel fuel to operate these vehicles. The Dane County BioMethane system won the 2011 Project of the Year Award from the U.S. Environmental Protection Agency.

Advantages and Disadvantages of Biomass Energy

Using biomass feedstocks and fuels provides a number of benefits for society and the environment. Biomass is a renewable resource when harvested sustainably. Biomass fuels can be produced from organic materials found throughout the world. Since most biomass is grown in rural areas, biomass fuel production can benefit rural

Facts about Biomass Fuels

economies by providing jobs. Using alcohol and biogas fuels and in motor vehicles helps conserve petroleum resources and reduces America's dependence on imported oil. Sulfur dioxide and mercury emissions from burning solid biomass fuels are much lower than those from burning coal. Sulfur dioxide, nitrogen oxide, and particulate matter emissions from biomass based alcohol and biodiesel fuels are also considerably lower than those of petroleum gasoline and diesel fuels. Emissions from burning biogas and biomass-produced methane are generally comparable to emissions from burning natural gas. Burning biomass fuels does release carbon dioxide, a suspected cause of global warming. However, the plants used to produce biomass consume carbon dioxide. For this reason, the various types of biomass are all generally considered to be net carbon neutral energy sources.

There are however also some drawbacks to using biomass fuels. Harvesting large areas to produce biomass fuels may harm wildlife habitats and may contribute to soil erosion. Repeatedly growing the same kinds of plants may reduce biological diversity. Biomass crops only grow part of the year, and crops may fail. This could disrupt supplies of biomass fuels. Removal of agricultural or forest wastes from the field may deprive the soil of nutrients. Burning municipal solid waste may produce toxic airborne emissions that require exhaust stack after treatment. Using land to produce biomass feedstocks may compete with land use for food production. Large amounts of energy are often needed to harvest crops and transport them. This may limit the use of certain types of biomass, and the locations of biomass facilities especially for large power plants.

Outlook

There are many types of biomass sources and value added biomass fuels, and the type of resource varies geographically. However, almost every part of the world has access to some type of biomass energy; this allows nations with different levels of technical development to meet their energy needs using biomass without having to import fossil fuels. The use of biomass has steadily increased over the past two decades. Although biomass is not likely to completely eliminate the use of fossil fuels in the near future, biomass can be used as a substitute to replace some of our consumption of coal, oil, and natural gas. Environmental impacts, competing land uses, the need for food, and the energy required to produce and harvest biomass material are limiting factors. Cultivating biomass sustainably and burning biomass fuels efficiently will help ensure that they are used wisely in the future.

References

Cliburn, J. K., and Associates. *Great Lakes Regional Biomass Energy Program: Activities and Accomplishments*. Chicago: Council of Great Lakes Governors, July 1994.

Flavin, Christopher, and Nicholas Lenssen. *Power Surge: Guide to the Coming Energy Revolution*. New York: W. W. Norton, 1994.

Office of Energy Efficiency & Renewable Energy. *2016 Billion-Ton Report*. Retrieved from: energy.gov/eere/bioenergy/2016-billion-ton-report.

Reddy, Amulya K. N., and Jose Goldemberg. "Energy for the Developing World." In *Energy for Planet Earth: Readings from Scientific American Magazine*. New York: W. H. Freeman, 1991.

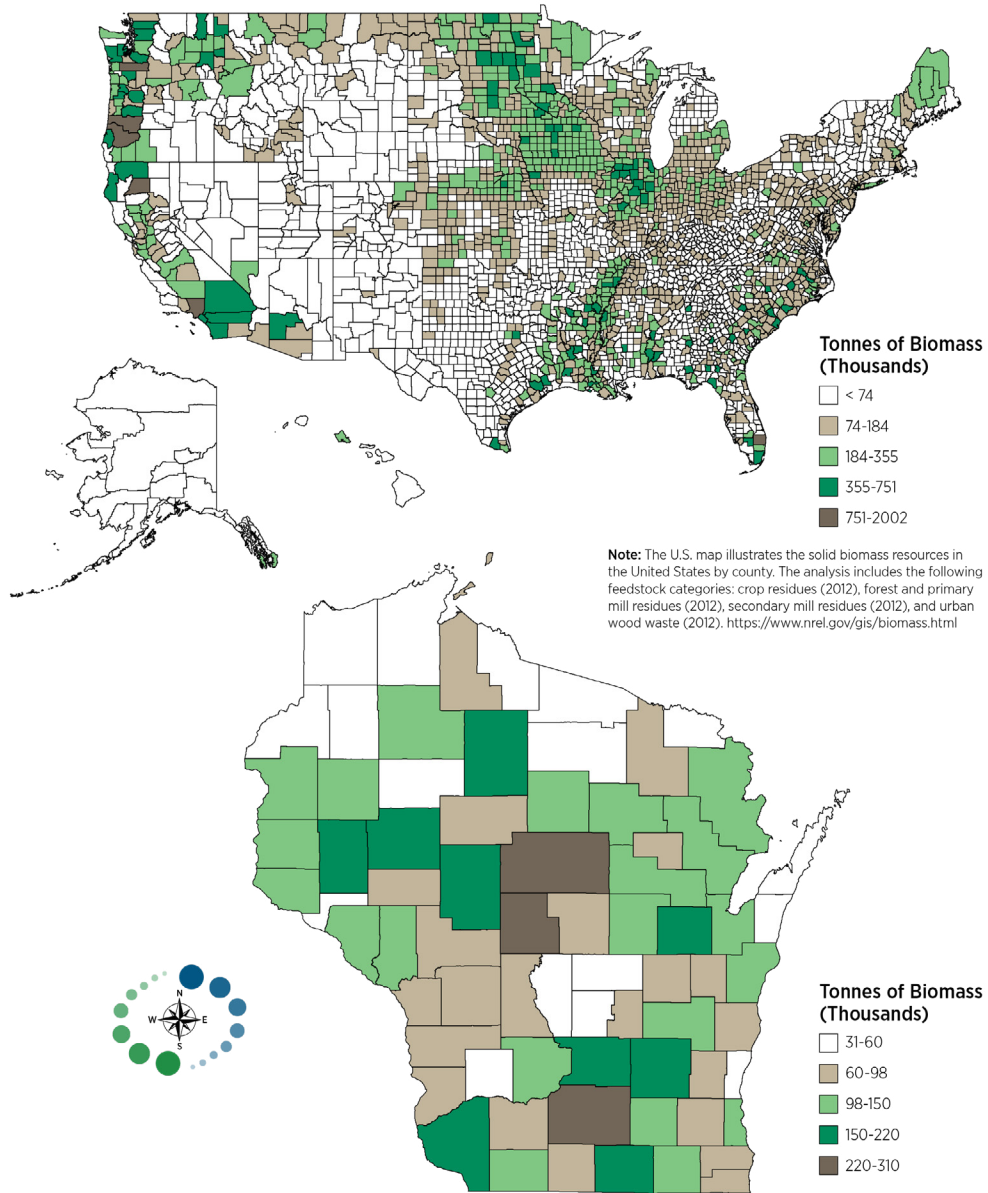
Renewable Energy Fact Sheet—Turning Wastewater into Energy. Focus on Energy. Madison, WI, 2002. Retrieved from: focusonenergy.com

U.S. Energy Information Administration: eia.gov.

Wisconsin Office of Energy Innovation. Wisconsin Energy Statistics Book: psc.wi.gov/Pages/Programs/OEI/WisconsinEnergyStatistics.aspx

Facts about Biomass Fuels

Biomass Resources Available in the United States and Wisconsin, 2015



Source: Wisconsin Office of Energy Innovation. [Wisconsin Energy Statistics Book](#).

© 2020 Wisconsin Center for Environmental Education

The Wisconsin K-12 Energy Education Program is supported through funding from



Wisconsin K-12 Energy Education Program (KEEP)
College of Natural Resources
University of Wisconsin - Stevens Point

