



Biomass Power Production

An Online Continuing Education Course for Engineers

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Biomass Power Generation

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Introduction

Biomass energy is the energy from plants and plant-derived materials and has been used since people began burning wood to cook food and keep warm. Wood is still the largest biomass energy resource today, but there are other sources of biomass. These include food crops, grassy and woody plants, residues from agriculture or forestry, oil-rich algae, and the organic component of municipal and industrial wastes. Even the methane from landfills can be used as a biomass energy source.

Bio-energy is renewable energy made from any organic material from plants or animals. Sources of bio-energy are called *biomass*, and include agricultural and forestry residues, municipal solid wastes, industrial wastes, and terrestrial and aquatic crops grown solely for energy purposes. Biomass is an attractive petroleum alternative because it is a renewable resource that is more evenly distributed over the Earth's surface than finite energy sources, and maybe exploited using more environmentally friendly technologies.



Today, biomass resources are used to generate electricity and power, and to produce liquid transportation fuels, such as ethanol and biodiesel. Ethanol is the most widely used liquid transportation fuel, or bio-fuel. Currently, a majority of ethanol is made from corn, but new technologies are being developed to make ethanol from a wide range of agricultural and forestry resources. Ethanol may be used as an alternative fuel, for example, in E-85 for flex-fuel vehicles, and may also be used as an octane-boosting, pollution-reducing additive to gasoline.

Biomass can be used for fuels, power production, and products that would otherwise be made from fossil fuels. In such scenarios, biomass can provide an array of benefits. For example: The use of biomass energy has the potential to greatly reduce greenhouse gas emissions. Burning biomass releases about the same amount of carbon dioxide as burning fossil fuels. However, fossil fuels release carbon dioxide captured by photosynthesis millions of years ago - an essentially "new" greenhouse gas. Biomass, on the other hand, releases carbon dioxide that is largely balanced by the carbon dioxide captured in its own growth.

The use of biomass can reduce dependence on foreign oil because biofuels are the only renewable liquid transportation fuels available.

Biomass has played a relatively small role in terms of the overall U.S. energy picture, supplying 5.0 quadrillion BTU of energy out of a total of 101 quadrillion BTU. The majority of it is used in the pulp and paper industries, where residues from production processes are combusted to

produce steam and electricity. Industrial cogeneration accounts for almost 3.0 quadrillion BTU of the biomass used in power generation. Outside the pulp and paper industries, only a small amount of biomass is used to produce electricity. There are power plants that combust biomass exclusively to generate electricity and facilities that mix biomass with coal (biomass co-firing plants). About 1.2 quadrillion BTU of biomass is used to generate electricity. The remaining biomass is consumed in residential and commercial applications in the form of wood consumption for heating buildings. To put these numbers in perspective, approximately 14 quadrillion BTU of coal and 30 quadrillion BTU of natural gas are consumed to generate electricity.

On a broader scale, biomass currently provides about 10% of the world's primary energy supplies, most being used in developing countries as fuel wood or charcoal for heating and cooking. It is estimated that the world biomass resource potential is over 240 quadrillion BTU's per year. Figure 1 shows the location of the world's biomass. The North American continent has almost 40 quadrillion BTU's of biomass potential.

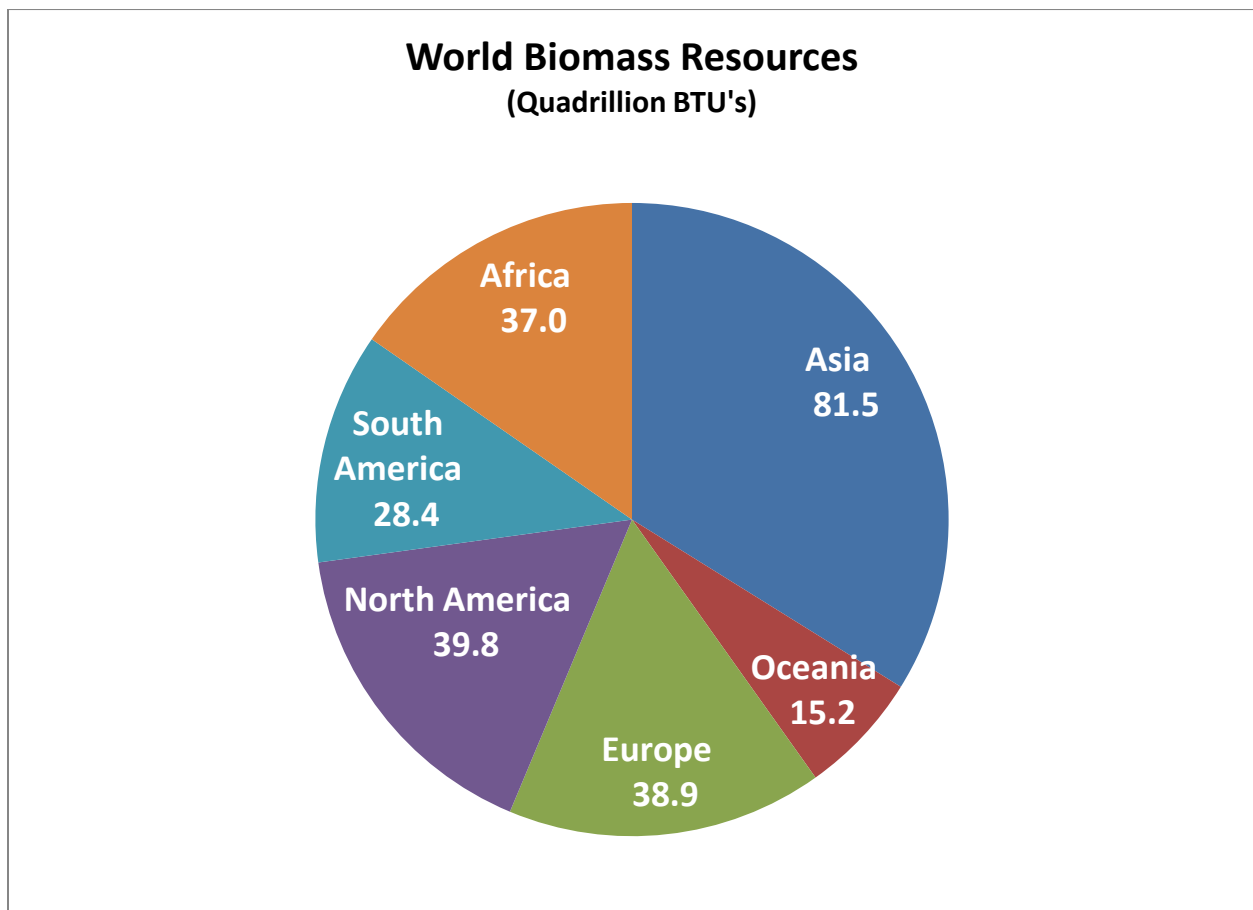


Figure 1

Unlike other renewable energy sources, biomass can be converted directly into liquid fuels, called *bio-fuels*, and are used to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel. Ethanol is an alcohol and is most commonly made by fermenting any biomass high in carbohydrates through a process similar to beer brewing. Ethanol is made from starches and sugars. Ethanol can also be produced by a process called gasification. Gasification systems use high temperatures and a low-oxygen environment to convert biomass into synthesis gas, a mixture of hydrogen and carbon monoxide. The synthesis gas or *syngas* can then be chemically converted into ethanol and other fuels. Ethanol is mostly used as blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing emissions. Biodiesel is made by combining alcohol (usually methanol) with vegetable oil, animal fat, or recycled cooking grease. It can be used as an additive to reduce vehicle emissions or in its pure form as a renewable alternative fuel for diesel engines.

In the current environment of low-cost fossil fuel supplies biomass power generation may be unable to compete. The inherent cost of power generation from biomass is high for two principal reasons:

1. Biomass is a low-density fuel, so fuel production, handling, and transportation are more expensive than for fossil fuels; and
2. Because of the dispersed nature of the resource, biomass power generating facilities tend to be small, so they cannot capture the economies of scale typical of fossil fuel-fired generating facilities. These characteristics leave biomass generation at a distinct disadvantage in a market that is increasingly driven by cost.

Processes

Bio-power, or biomass power, is the use of biomass to generate electricity. Bio-power system technologies include direct-firing, co-firing, gasification, pyrolysis, and anaerobic digestion. Most biopower plants use direct-fired systems. They burn biomass feedstocks directly to produce steam. This steam drives a turbine, which turns a generator that converts the power into electricity. In some biomass industries, the spent steam from the power plant is also used for manufacturing processes or to heat buildings. Such combined heat and power systems greatly increase overall energy efficiency. Paper mills, the largest current producers of biomass power, generate electricity or process heat as part of the process for recovering pulping chemicals. Co-firing refers to mixing biomass with fossil fuels in conventional power plants. Coal-fired power plants can use co-firing systems to significantly reduce emissions, especially sulfur dioxide emissions.

Gasification systems use high temperatures and an oxygen-starved environment to convert biomass into synthesis gas, a mixture of hydrogen and carbon monoxide. The synthesis gas, or *syngas*, can then be chemically converted into other fuels or products, burned in a conventional boiler, or used instead of natural gas in a gas turbine. Gas turbines are very much like jet engines, and have high efficiencies. High-efficiency to begin with, they can be made to operate in a *combined cycle*, in which their exhaust gases are used to boil water for steam, a second round of power generation, and even higher efficiency. Using a similar thermo-chemical process but different conditions (totally excluding rather than limiting oxygen, in a simplified sense) will pyrolyze biomass to a liquid rather than gasify it. As with syngas, pyrolysis oil can be burned to generate electricity or used as a chemical source for making fuels, plastics, adhesives, or other bio-products.

The natural decay of biomass under anaerobic conditions produces methane, which can be captured and used for power production. In landfills, wells can be drilled to release the methane from decaying organic matter. Then pipes from each well carry the methane to a central point, where it is filtered and cleaned before burning. This produces electricity and reduces the release of methane (a very potent greenhouse gas) into the atmosphere.

Gasification, anaerobic digestion, and other biomass power technologies can be used in small, modular systems with internal combustion or other generators. These could be helpful for providing electrical power to villages remote from the electrical grid—particularly if they can use the waste heat for crop drying or other local industries. Small, modular systems can also fit well with distributed energy generation systems.

Biomass Fuel or Feedstock

The main biomass feedstocks for power are paper mill residue, lumber mill scrap, and municipal waste. For biomass fuels, the most common feedstocks used today are corn grain (for ethanol) and soybeans (for biodiesel). In the near future agricultural residues such as corn stover and wheat straw will also be used. Long-term plans include growing and using dedicated energy crops, such as fast-growing trees and grasses, and algae. These feedstocks can grow sustainably on land that will not support intensive food crops.

Corn stover is the stalks, leaves, and husks of the plant.

Biomass can be purpose-grown as fuel or it can be the byproduct of, or residual from, another process. The advantage of purpose-grown biomass is the stability of supply of biomass fiber and increased efficiency in harvesting the biomass. The main disadvantage of purpose-grown biomass is that it can compete with other uses for the land or the product. For example, using some types of roundwood as a fuel source would take that supply "out of circulation" for the

lumber and pulp/paper industries. Using residual biomass is typically less expensive and competes less directly with the primary use for that biomass. This is especially important for agricultural products. However residual biomass, such as corn stover and tree branches, is not always harvested with the primary material, making collection difficult.

Biomass fuel can also be "raw" or pelletized. The process of pelletizing the fuel typically increases the BTU content by removing moisture from the biomass. It also standardizes the fuel's size and shape. However, pelletizing the biomass is typically energy-intensive and requires the capital cost of the pellet plant as well as drying and pelletizing equipment.

Biomass Benefits

Because biomass technologies use combustion processes to generate electricity, they can generate electricity at any time, unlike wind and solar which only produce when the wind is blowing or the sun is shining. Biomass has the second-largest amount of renewable energy in the U.S. Biomass generation is second only to hydropower and wind. Biomass has always been used to generate power. Biomass has always been used to generate power to the U.S. grid. Biomass generators supply 71% of the U.S. independent biomass power.

Energy production from biomass conversion processes, while avoiding the environmental impacts of energy from fossil fuels, such as landfill burial of biomass residues used as fuel, biomass conversion facilities avoids the environmental impacts of biomass conversion facilities. Biomass conversion facilities avoid the environmental impacts of biomass conversion facilities. Biomass conversion facilities avoid the environmental impacts of biomass conversion facilities. Biomass conversion facilities avoid the environmental impacts of biomass conversion facilities.

In this course we will look at biomass conversion technologies in detail and discuss the environmental issues associated with biomass energy. Finally, we will look at the environmental issues associated with biomass energy.

