An Introduction to Biomass Heating

Introduction

One way to make Pennsylvania more energy independent is to purchase and use locally produced biomass fuel for heating. Doing so would not only support the local economy, but it is also relatively inexpensive and can be ecologically beneficial.

Biomass (any recently growing material such as trees or field crops) has actually been used as a heat source in Pennsylvania for centuries. Originally, it was used in the form of wood fires outside or in crude indoor fireplaces. These early approaches were only marginally effective at keeping people comfortable in an efficient way. Over the years, advances in technology (including the famous "Franklin stove" of colonial Pennsylvania) have improved our ability to burn biomass fuels effectively. The ability to control and optimize biomass combustion has now reached the point where the technology for large combustion systems is quite sophisticated and very efficient.

The Combustion Process

Biomass combustion is a chemical reaction—the combination of oxygen and biomass at a high temperature—that produces heat, water vapor, ash, and CO_2. "Complete combustion" results in only those four products. If the combustion process is incomplete, then uncombusted or partially combusted material, in the form of soot and creosote, is also generated. As a particle of biomass combusts, it undergoes three main processes:

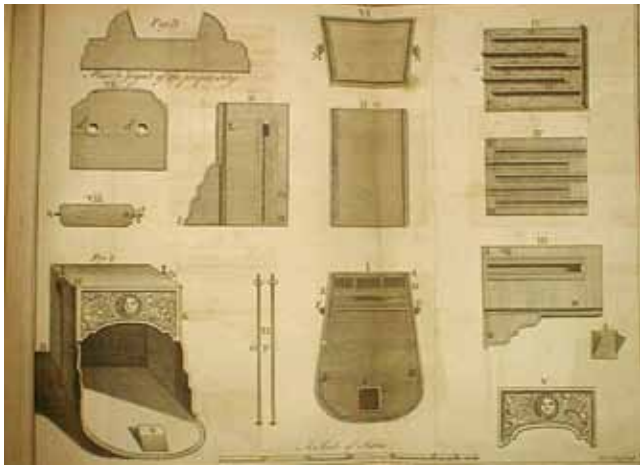
- Heating and drying: The biomass is heated and any water in the material is "boiled off." The amount of energy required to vaporize the water is quite high and can reduce the overall combustion heat output.
- Flaming combustion: When the biomass temperature reaches the 200-300°C range, molecules in the biomass begin to break down, forming combustible gases. These gases react with oxygen and release heat, causing visible flames.
- Char combustion: The portion of biomass that does not break down into combustible gases (primarily carbon) also reacts with oxygen and releases heat. Glowing coals in a fireplace are a good example of char combustion.

A well-designed and efficient combustor provides for these three processes by furnishing heat and oxygen in the locations and quantities needed.

Gasification combustion is a slight variation on the combustion process. In this form of combustion, the biomass is heated in an oxygen-reduced container until the molecules break down to form combustible gases (primarily carbon monoxide, methane, and hydrogen). These gases are then fed into a combustion chamber where they are burnt, much in the same way that natural gas or propane is combusted.

Fuel Choices

It is with good reason that wood remains the traditional favorite feedstock for combustion systems in Pennsylvania.



Franklin Stove, 1769

Flaming combustion

Not only is wood plentiful in the Keystone State, but it also burns well and produces minimal ash (provided the bark is removed). Wood can be used as a fuel in the form of cordwood (logs), chips, and sawdust, or as compressed pellets, briquettes, or cubes. Green chips (not dried) are the most common fuel for commercial combustors because of their availability, low price, and compatibility with automated handling systems. Charcoal is also a potential biomass fuel, especially for the purpose of "co-firing," where it is mixed with coal in large power plants and industrial combustors.

Several types of biomass other than forest wood can also be used as combustion fuel. Some of the more common options include:

- Short-rotation woody crops, such as poplar and willow, which grow quickly and can be produced as a mechanized field crop. The trees are harvested every few years, with shoots growing up from the harvested stump. Typically, the stalks are chipped and the fuel is used much like ordinary wood chips.
- Field crop residues, such as wheat straw or corn stover, can also be used as a biomass fuel. They can be burnt as is, or they can be chopped and pressed into densified fuel pellets.
- There is great opportunity for growing grasses, such as miscanthus or switchgrass, as a combustion fuel, especially on marginal lands not sufficiently productive for other crops.
- Plant oils or animal fats can be burned as a heating fuel, although these materials are more commonly transformed into biodiesel for use as a transportation fuel.
- Grains can serve as a combustion fuel, with corn being the most common type in use today.
- Even animal waste can be utilized as a fuel for combustion if it is sufficiently dry. However, this is not a common fuel in Pennsylvania.

Biomass fuel briquettes

Many options are available when it comes to selecting a biomass fuel. Not only is the type of material important to consider, but other properties, such as size and moisture content, need to be considered as well. When comparing different biomass fuels, keep in mind that biomass fuel tends to have more variability in composition and performance than fossil fuels. Even premium biomass fuels such as wood pellets, which are manufactured to specific standards, can vary noticeably in performance from brand to brand. Therefore, biomass combustion equipment is usually designed to handle a range of fuel properties rather than one precise type of fuel.

A common concern about the use of biomass as a fuel is the question of ecological sustainability. After all, our rate of energy use in Pennsylvania is much greater than our current ability to grow biomass energy. If we were to try to meet a large fraction of our total energy needs from biomass, we would likely deplete our forests and fields in short order. Therefore, it is important that any biomass production or harvesting be done in a manner that protects the ecosystem and preserves our natural resources.

Fortunately, this is not likely to be a major problem in Pennsylvania. The state's farms and forests, while not perfect, have been operating in an increasingly ecologically sound manner for many years, producing food and timber for the needs of the state and beyond. Biomass used for energy is a commodity of much lower value than when it is used for either food or timber, and farmers and foresters are usually too smart to damage their land for the sake of a relatively small return from biomass energy.

In addition, regulations and guidelines are in place to help protect the land's long-term productivity. Biomass energy production can actually serve as a valuable management tool by providing an economical way to remove undesirable species from forests or by putting marginal land that is not otherwise useful into production. Some studies have suggested that bioenergy crops, if properly grown, could significantly reduce fertilizer runoff, erosion, and other problems associated with some farming operations.

Equipment for Biomass Heating

The equipment needed for biomass heating varies, depending on the type of fuel that is used. Such equipment is typically more expensive than comparable devices that use fossil fuels, but the lower cost of the biomass fuel can save money for the owner in the long run. Typical equipment includes:

- Wood stoves and fireplace inserts: These are almost exclusively residential devices, which burn cordwood that is manually fed into the device.
- Outdoor wood furnaces: These devices are similar to a woodstove, except that they are located outside, with heat piped into the home in the form of hot water. Their main

Table 1. Common fuels and their relative costs.

Fuel	Typical delivered price	Fuel heating value (HHV)	Typical combustor efficiency (%)	Cost per unit energy ($/GJ)
Cordwood, 30% moisture, delivered	$150 per cord	14.1 MJ/kg	60	13.36
Clean, green wood chips, 40% moisture	$50 per ton	12.1 MJ/kg	80	5.73
Dried wood chips, 20% moisture	$70 per ton	16.1 MJ/kg	80	5.72
Premium hardwood pellets, 5% moisture	$6 per 22 kg bag	18.1 MJ/kg	80	18.83
Switchgrass pellets, 5% moisture	$6 per 22kg bag	17.2 MJ/kg	80	19.82
Natural gas	$12 per 1000 cf	38.3 MJ/m^3	80	15.35
Fuel oil	$2.50 per gallon	36.4 MJ/liter	80	22.78
Coal	$110 per short ton	28 MJ/kg	75	5.12
Electricity (resistance heat)	$0.12 per kWh	3.6 MJ/kWh	100	33.33

GJ = gigajoule; MJ = megajoule; kWh = kilowatt hour; HHV = higher heating value

advantage is that the mess of feeding wood into the combustion chamber is kept out of the home.

- Pellet stoves: Pellet stoves are designed to combust pelletized fuel, and many allow for automatic feed of the fuel into the combustion chamber. They tend to be more thermally efficient than woodstoves and outdoor furnaces, but the fuel is generally more expensive.
- Commercial-scale biomass boilers: Large, commercial-scale biomass boilers are designed for use in schools, office buildings, hospitals, and other large structures. They utilize automatic feed systems and advanced computerized controls to maximize the efficiency and performance of the equipment.

Obtaining Biomass Fuels

While growing your own fuel is an attractive option, many people do not have the land available to do so; instead, they purchase the fuel from an outside provider. Biomass fuels are generally a very economical choice, with cost savings of up to 50 percent or more when compared with fossil fuels. This fact is not always clear at first glance, because the various types of fuel are often sold in different units. For example, wood chip fuel is sold by the ton, whereas fuel oil is sold by the gallon. Comparing fuels on a "per unit of energy" basis (i.e., per gigajoule, GJ) is the best way to compare the actual costs of different fuel options (see Table 1).

From the prices shown in the table, coal is the only fossil fuel that is cost competitive with biomass when the fuels are adjusted for their energy content. The Energy Selector tool, available from Penn State Cooperative Extension, is a valuable resource for assessing the actual value of fuels at different prices.

The availability of biomass fuel depends on your location and fuel needs. Wood chips are a commonly sold commodity for pulp and paper production. Most locations in the Keystone State are within easy reach of a forest products company that can supply wood fuel. Farm-based biomass fuel is not yet as readily available, and finding it depends on locating a nearby farmer who is willing to meet your needs.

Supply contracts for biomass fuel should include a "fuel specification" that outlines the required volume and properties of the fuel to be supplied. At a minimum, the fuel should be completely free of dirt and rocks, should have a moisture content within an acceptable range, and should have maximum and minimum particle dimensions that are compatible with your fuel-handling and combustion systems.

Pollution and Emissions from Biomass Combustion

Old-fashioned woodstoves and boilers were known for their smelly smoke, and some residential woodstoves in use today still have this problem, depending on the fuel and the manner in which it is operated. However, commercial-scale combustors, thanks to computer controls and other developments, are able to combust biomass very cleanly, with no visible smoke or odor. On cold days, steam is sometimes seen condensing above the stack, but this is not smoke or soot. These biomass combustors can meet all requirements for air quality, and they operate well in sensitive areas such as hospitals and schools.

In addition, biomass fuels are essentially "carbon neutral," meaning that they recycle CO_2 in the atmosphere rather than adding to it. However, it should be noted that emissions of nitrogen oxides (NOx) and particulates (PM), while well within governmental limits, can be similar to or sometimes higher than those from fossil fuels (see Table 2).

Table 2. Typical emissions from a commercial biomass combustor.

Parameter	Typical range of emissions (g/MJ)	
	Low	High
Total particulate matter (TPM)	0.0391	0.0875
Particulate matter less than 2.5 microns diameter (PM 2.5)	0.0030	0.0335
Condensible particulate matter (CPM)	0.0598	0.1068
Nitrogen dioxide (NO_2)	0.0486	0.1251
Carbon monoxide (CO)	0.0370	0.1913

Source: Hinckley, 2008.

Air quality regulations in Pennsylvania require that any combustor using fuel at a rate above 730 kw (2.5 million btu/h) be approved by the state Department of Environmental Protection (DEP). A "plan approval" must be submitted before construction, and an "operating permit" must be obtained shortly after completion of the installation. The operating permit requires testing to confirm that emissions from the combustor are within limits set by state code.

Extremely large combustors are governed by federal standards (known as Title V), but authorization is still administered by the state. Specific emissions limits depend on the size of the facility and its location (urban areas have stricter standards); contact your local Department of Environmental Protection office for current regulations and procedures.

Conclusion

Biomass is a very good fuel option for heating buildings in Pennsylvania. It is locally produced, widely available, and quite economical when compared with other common fuels. However, biomass does have unique characteristics that should be well understood if one is to use it to full advantage. Probably the greatest motivator for using biomass fuel is the cost savings that come from its use, although its ecological and local economic benefits should not be ignored. While residential combustion of wood historically has been the major use of biomass heat, larger systems for commercial buildings and industrial processes have a great deal of promise. For further information, see the related fact sheets Characteristics of Biomass as a Heating Fuel and Commercial Biomass Heating Equipment.

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Penn State Cooperative Extension's Renewable and Alternative Energy Program: **energy.extension.psu.edu**

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