Characteristics of Biomass as a Heating Fuel

Introduction

Biomass is a promising option for providing locally produced, renewable energy in Pennsylvania. While it is not unusual for homes in the state to be heated with firewood, other forms of biomass fuel are not as common and commercial-scale use of biomass fuel is very limited. A person who plans to use biomass for fuel or design equipment for biomass heat needs to understand the performance characteristics of biomass in order to avoid possible problems and utilize the biomass effectively. Biomass can be a source of liquid fuel (e.g., biodiesel) or gaseous fuel (e.g.,"wood gas"), but the most common use is as a solid fuel (e.g., wood, biomass pellets). This fact sheet presents some of the more important characteristics of solid biomass fuel and explains their significance.

Biomass Fuel Performance

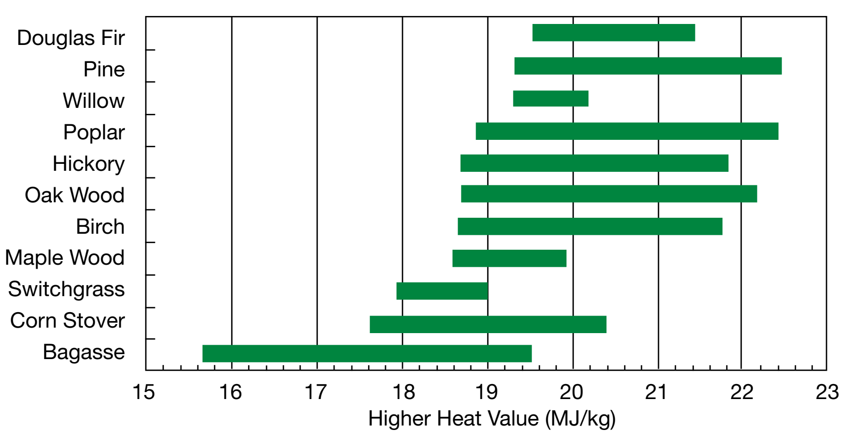
Heat Value

The heat value, or amount of heat available in a fuel (kJ/kg), is one of the most important characteristics of a fuel because it indicates the total amount of energy that is available in the fuel. The heat value in a given fuel type is mostly a function of the fuel's chemical composition.

The heat value can be expressed in one of two ways: the higher heating value or the lower heating value. The higher heating value (HHV) is the total amount of heat energy that is available in the fuel, including the energy contained in the water vapor in the exhaust gases. The lower heating value (LHV) does not include the energy embodied in the water vapor. Generally, the HHV is the appropriate value to use for biomass combustors, although some manufacturers may utilize the LHV instead, which can lead to confusion.

Some species of biomass tend to have more energy per unit of mass than others. However, the variation between species is often no greater than the natural variations found within one species or another. The heat content of a fuel type can vary significantly depending on the climate and soil in which the fuel is grown, as well as other conditions. As a result, the energy content of a biomass fuel should be thought of as a range rather than a fixed value. Figure 1 shows the typical range of some common fuels. The most important noticeable trend in these data is that wood (which has a lower ash content) tends to have a slightly higher heat value than field crops.

Figure 1. Heat content of various fuels (oven dry). One MJ (megajoule) is enough energy to brew about 10 cups of coffee if your pot is 100 percent efficient. It is also equal to about 1,000 BTUs.



Moisture Content

Fresh,"green"wood is often about half water, and many leafy crops are primarily water. A low moisture level in the fuel is usually preferable because high-moisture fuels burn less readily and provide less useful heat per unit mass (much of the energy in wet fuel is used to heat and vaporize the water). Extremely dry fuel, however, can cause problems such as dust that fouls equipment or can even be an explosion hazard.

The moisture content in a fuel can be calculated by one of two methods: wet basis or dry basis. In the case of wet-basis calculations, the moisture content is equal to the mass of water in the fuel divided by the total mass of the fuel. In the case of dry-basis calculations, the moisture content is equal to the mass of water in the fuel divided by the mass of the dry portion of the fuel. It is important to know which type of calculation is being used, as the two values can be quite different in magnitude. For example, a 50 percent wet-basis moisture level is the same as a 100 percent dry-basis moisture level.

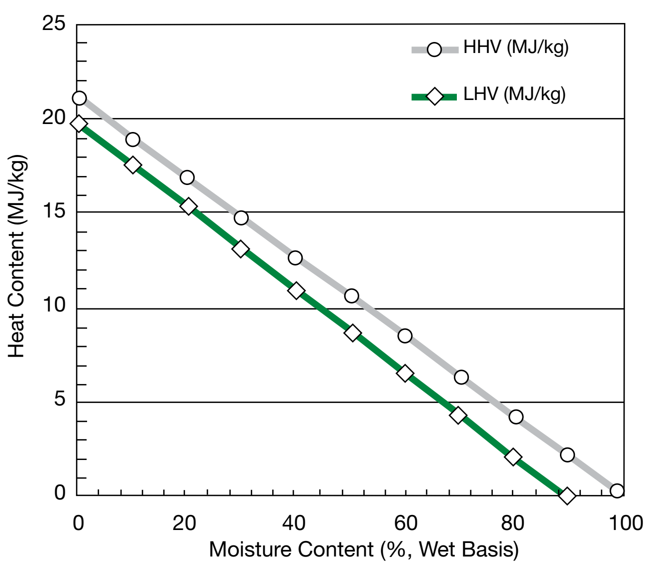
The practical maximum moisture level for combusting fuel is about 60 percent (wet basis), although most commercial equipment operates tolerably well with fuels that only have up to about 40 percent moisture. The HHV and LHV of wood fuel is shown in Figure 2 as a function of fuel moisture content.

Composition

In addition to heat content, other differences in fuel performance are related to composition of the various biofuels. The three most significant compositional properties are (1) ash content, (2) susceptibility to slagging and fouling, and (3) percent volatiles.

Ash content (the mass fraction of uncombustible material) is an important parameter, with grasses, bark, and field crop residues typically having much higher amounts of ash than wood. Systems that are designed to combust wood can be overwhelmed by the volume of ash if other biofuels are used, which can reduce the combustion efficiency or clog the ash-handling mechanisms.

Figure 2. Typical biomass higher heating value and lower heating value versus moisture content.



Slagging and fouling are problems that occur when the ash begins to melt, causing deposits inside the combustion equipment. Ash ideally remains in a powdery form at all times. However, under some conditions, the combustion ash can partially melt, forming deposits on the combustor surfaces (fouling) or hard chunks of material in the base of the combustion chamber (slagging/clinkering). Certain mineral components in biomass fuels, primarily silica, potassium, and chlorine, can cause these problems to occur at lower temperatures than might be expected.

Many studies have observed that the high mineral content in grasses and field crops can contribute to fouling and clinkering—a potentially expensive problem for a combustion system. The timing of harvest can affect this property, with late harvested crops having noticeably lower ash content (Adler et al., 2006). Dirt in the fuel also adds to the mineral content and associated clinkering and fouling problems; therefore, fuel should be kept free of soil and other contaminants.

Slagging and fouling can be minimized by keeping the combustion temperature low enough to prevent the ash from fusing. Alternately, some biomass combustion equipment uses an opposite approach—it is designed to encourage the formation of clinkers but is able to dispose of the hardened ash in an effective manner. Table 1 shows a "slagging index" and a "fouling index" for several fuels, which are two measures that give some indication of the tendency of a fuel to form slag or foul a boiler. Values lower than 0.6 are preferable. These indices were developed for use with coal, however, and their significance for use with biomass fuels is questionable. Treat these values with caution.

The "percent volatiles" in a fuel is a less commonly known property that refers to the fraction of the fuel that will readily volatilize (turn to gas) when heated to a high temperature. Fuels with "high volatiles" will tend to vaporize before combusting ("flaming combustion"), whereas fuels with low volatiles will burn primarily as glowing "char." This property affects the performance of the combustion chamber and should be taken into account when designing a combustor.

Fuel Size and Density

The size and density of the biomass fuel particles is also important. They affect the burning characteristics of the fuel by affecting the rate of heating and drying during the combustion process. Fuel size also dictates the type of handling equipment that is used. The wrong size fuel will have an impact on the efficiency of the combustion process and may cause jamming or damage to the handling equipment. Smaller-sized fuel is more common for commercial-scale systems because smaller fuel is easier to use in automatic feed systems and also allows for finer control of the burn rate by controlling the rate at which fuel is added to the combustion chamber. Fuel size and density are probably the most overlooked factors affecting fuel performance and should be given careful consideration when selecting a fuel type.

Conclusion

Several characteristics affect the performance of biomass fuel, including the heat value, moisture level, chemical composition, and size and density of the fuel. These characteristics can vary noticeably from fuel to fuel. In addition, natural variations of a given fuel type can be significant. Combustion equipment can and should be designed to handle this range of properties. For further information on biomass heating, see the other related Renewable and Alternative Energy Fact Sheets *An Introduction to Biomass Heat* and *Commercial Scale Biomass Combustors*.

Table 1. Examples of ash, slagging, fouling, and volatiles.

Fuel	Percent ash content	Slagging index	Fouling index	Percent volatiles	Reference
Wood, clean and dry	0.3	0.05	7	82	20
Bark, dry	1.2	5.6	34	70	17
Switchgrass	5.2	0.06	4.2	76	8
Corn stover	5.6	0.04	8.2	75	26
Coal	12	0.08	0.13	35	26

These values are representative only and can be expected to vary depending on cultivar, soil, weather, and cultural practice. While some variations in composition do exist between tree species, the properties of wood fuel, on a per-kilogram basis, are surprisingly similar for common species in Pennsylvania.

Table 2. Typical size and density of biomass fuels.

Fuel	Length (m)	Bulk density (kg/m^3)
Sawdust	0.0003–0.002	300
Chopped straw	0.005–0.025	60
Green wood chips	0.025–0.075	500
Wood pellets	0.006–0.008	600
Biomass briquettes	0.025–0.010	600
Cordwood	0.3–0.5	400

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Penn State College of Agricultural Sciences research, extension, and resident education programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

This publication is available from the Publications Distribution Center, The Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802. For information telephone 814-865-6713.

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Produced by Ag Communications and Marketing

Code # **UB043** 4M3/10acg4942