

## Co-firing Biomass with Coal

### Introduction

Pennsylvania farmers and foresters that are interested in growing biomass as an energy crop have a wide variety of potential markets for their product. One of the more promising options is to sell your biomass for co-firing with other fuels, especially coal. Several experimental tests have been run over the years to co-fire biomass with coal, including tests at the Shawville power plant in Clearfield County and the Seward power plant in Westmoreland County. These and other experiments have given us a good indication of the problems and benefits associated with co-firing. This fact sheet provides an introduction to co-firing, including a description of the process and a discussion of the issues associated with co-firing biomass.



### What Is Co-firing?

Co-firing is the burning of more than one type of fuel simultaneously. Usually, the term is used to describe the combination of coal with another fuel source.

The fuel can be mixed with the coal outside the combustor, or the fuels can be added to the combustor separately. The most common type of facility for co-firing is large, coal-fired power plants. However, other coal-burning facilities, such as cement kilns, industrial boilers, and coal-fired heating plants, are good candidates for co-firing as well.

### Coal versus Biomass

One of the reasons biomass is a good candidate for co-firing with coal is that both biomass and coal are solid fuels. Therefore, equipment designed to burn coal should be able to easily use biomass as well—you would think. However, coal and biomass are not exactly the same, and you need to understand

the differences between the two types of fuel if you are to co-fire effectively.

First, the chemical composition of coal is different from that of biomass (Table 1). Most notably, biomass has a higher fraction of hydrogen and oxygen, and less carbon than coal. As a result, biomass tends to generate less energy than coal—about two-thirds as much, on a mass basis.

In addition, the differences in composition cause biomass to have a higher fraction of volatile matter, which causes it to have more “flaming combustion” and less “char combustion” (glowing coals). This difference can affect the optimum sizing and design of the combustion chamber, as well as the ideal flow rate and location of combustion air.

**Table 1. Typical elemental composition of Pennsylvania coal and biomass.**

Fuel	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Silicon	Potassium	Calcium	Chlorine
	(percent)								
Anthracite coal	91–94	2–4	2–5	0.6–1.2	0.6–1.2	2–6	0.1–0.5	0.03–0.2	0.01–0.2
Bituminous coal	83–89	4–6	3–8	1.4–1.6	1.4–1.7	2–3	0.1–0.2	0.1–0.3	0.01–0.13
Wood, clean and dry	50	6.1	43	0.2	—	0.05	0.1	0.04	—
Switchgrass	48	5.5	43	0.2	—	1.4	0.4	0.2	—

Source: Miller and Tillman (2008) and Bain et al. (2003).

Biomass also tends to be less dense than coal. For example, pulverized coal, at 850 kg per m<sup>3</sup> (kilograms per cubic meter), is nearly seven times denser than baled straw (150 kg per m<sup>3</sup>). This means that fuel feed systems will need to handle and deliver much higher volumes of fuel if co-firing is used.

The ash from biomass is also different from coal (Table 2). Coal has a much higher ash content than biomass. However, biomass ash is more prone to forming deposits within the combustor, called “slagging” and “fouling.” This is due to the fact that biomass ash contains relatively reactive salt compounds (especially K<sub>2</sub>O), rather than the more stable silicates found in coal ash. If the co-firing fraction (mass fraction of biomass fuel relative to the total) is high (i.e., 30 percent or higher), slagging and fouling can be a significant problem in the combustor. However, low-fraction co-firing (~5 percent) appears to cause no noticeable problems with the equipment.

Moisture content is different between coal and biomass. Freshly harvested biomass is often 50 percent water (or higher). Freshly mined bituminous and anthracite coal are less than 10 percent water. If dry biomass is stored in a large outdoor pile and it is rained on, the biomass tends to absorb the water and begin to decompose. If a pile of coal is rained on, the water drains through with minimal damage to the fuel.

These differences are important when considering the supply and storage of fuel for co-firing. One possible method for reducing these problems is to convert the biomass to charcoal (sometimes called “biochar” or “torrefied biomass”). Charcoal is much less prone to decomposition than fresh biomass and has a consistency similar to that of coal. It is also possible to densify biomass fuel into hard pellets or briquettes that may be more compatible with a combustor’s fuel handling system.

Finally, it is important to note that biomass and coal can be processed to a variety of sizes, which affects their handling and combustion characteristics. Most coal-fired power plants use “pulverized coal,” a fine powder with particles less than

1 millimeter in size. Biomass fuel for co-firing may need to be ground to a small size as well, depending on the characteristics of the equipment.

### Performance of Co-fired Fuel

More than 100 commercial-scale co-firing tests have been carried out on a variety of biomass-coal blends and several types of combustion equipment. The consensus of these tests seems to be that biomass, when co-fired at low percentages, burns cleanly and effectively. High percentages of biomass, however, can lead to problems, especially in terms of increased fouling and slagging of ash within the combustor. The maximum safe co-firing rate is not a hard and fast number. Most tests have shown no problems at a rate of 5 percent. Many tests show no problems with co-firing up to 30 percent, provided that the fuel-handling and feed equipment is compatible with the biomass fuel.

However, the specific characteristics of the fuel and the combustor make it very difficult to predict with certainty the maximum recommended co-firing rate. Fuel mixtures can have characteristics that are noticeably different from those of the individual components. Therefore, it is best to conduct careful tests, with monitoring, at the start of the co-firing period. This will ensure that combustion is taking place in a clean and effective manner. Some types of combustors (e.g., fluidized bed systems) are more “fuel flexible” than others, which can allow for easier co-firing.

### Why Co-fire?

There are two main reasons to consider co-firing: one for the grower/producer, and one for the buyer. From the farmer or forester’s perspective, co-firing creates an extremely large market for biomass fuel. Currently, Pennsylvania uses approximately 57 million tons of coal per year. If 5 percent of the fuel (on an energy basis) were replaced with biomass, this would amount to 4.4 million tons of biomass per year. This

**Table 2. Typical chemical composition of coal and biomass ash.**

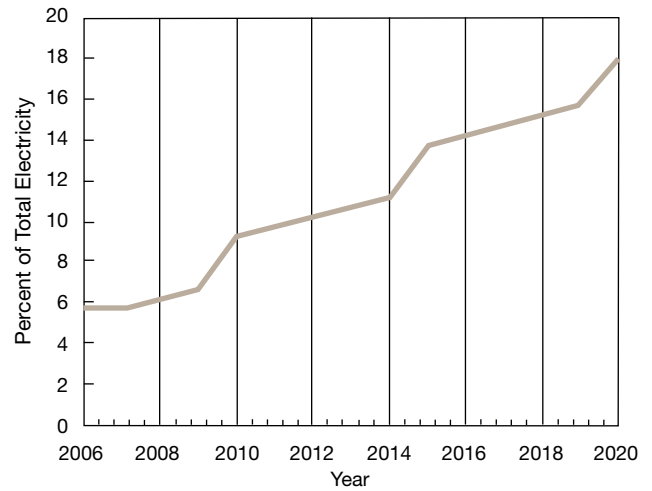
Fuel	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	TiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	SO <sub>3</sub>
	(percent)									
Bituminous coal	41–66	22–31	4–10	1–9	0.5–3.5	0.1–0.8	0.3–3.1	0.7–2.2	0.2–1.0	0.3–7.6
Anthracite	59–65	20–21	5–8	1–4	1–1.9	0.5–0.9	4.0–5.0	0.9–1.3	0.06–0.25	2.0
Pine chips	67.8	7	5.4	7.8	2.4	1.2	4.5	0.5	1.5	0.2
Switchgrass	65.2	4.51	2.0	5.6	3	0.6	11.6	0.2	4.5	0.4

Source: Miller and Tillman (2008) and Bain et al. (2003).

would nearly triple the current rate of biomass use for energy. As another example, consider a 1,000-megawatt power plant (a typical large plant by today's standards). Co-firing at a 5 percent rate would require approximately 245,000 tons of biomass per year, which would require about 50,000 acres of high-yield production. In addition to this being a large potential market, the possibility exists to obtain long-term supply contracts from power producers, which could reduce the risk associated with growing the crop, especially perennial crops such as grasses or short-rotation woody crops, which require several years before they are ready for harvest.

When we consider the buyer's perspective, the main benefit of co-firing is that it reduces pollution emission from the plant. Biomass is virtually free of sulfur and mercury, which leads to reductions in emissions that are proportional to the amount of biomass being used. Biomass is also essentially "carbon neutral," which is important when you consider the growing levels of concern and regulation surrounding the release of carbon dioxide from fossil fuels. Even a 5 percent reduction in emissions can make the difference between meeting or missing an emissions target set by the government. The one pollutant that does not appear to be affected greatly by co-firing is the production of nitrogen oxides (NOx). Adding biomass can cause NOx emissions to rise or fall slightly; this is a complicated function of the design of the boiler and the manner in which it is operated.

**Figure 1. Percentage of electricity production to come from alternate sources, as per Pennsylvania State Law HR6.**



Power plants have an additional incentive for co-firing biomass in Pennsylvania: the state's Alternative Fuels Portfolio Standard. This is a state mandate that requires a certain percentage of Pennsylvania's electricity to be from renewable or alternative energy sources. Biomass co-firing is one of the most promising ways to meet that standard, although the total availability of biomass in Pennsylvania may not be sufficient to meet the standard's ambitious goals.



## Conclusion

Co-firing biomass is a good option for coal-fired combustors in Pennsylvania because

- the solid biomass fuel can be added to the fuel stream,
- the addition of biomass to the fuel reduces emissions of sulfur, and
- biomass fuel is essentially carbon neutral.

However, there are some challenges associated with biomass co-firing, including

- handling and storage challenges, and
- the potential for fouling and slagging at high co-firing rates.

At low to moderate biomass-to-coal ratios, co-firing appears to have the best overall performance for reducing emissions and ensuring trouble-free operation in a coal-fired combustion system.

## References

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