**Biomass Cofiring R&D and Demonstration Results for Handling, Combustion, Heat Transfer, and Emissions Issues for Coal-Fired Boilers**

M.C. Freeman*[a], W.J. O'Dowd[a], S.I. Plasynski[a], G.F. Walbert[b]
[a]U.S. Department of Energy National Energy Technology Laboratory,
P.O. Box 10940, Cochrans Mill Road, Pittsburgh, Pennsylvania, USA 15236
Fax: 412-386-6004; mfreeman@netl.doe.gov
[b]Parsons Infrastructure and Technology, Inc.

This paper discusses cofiring studies of various biomass fuels - including pentachlorophenol (PCP) and creosote-treated wood, lumber mill and furniture waste sawdusts, pallets, feedlot biomass (cattle manure), hybrid willow, and switchgrass – with several bituminous and subbituminous coals. This paper is presented to discuss general combustion/emissions issues with biomass cofiring, as well as specific issues with particular biomass fuels, such as slagging/fouling. Biomass cofiring in large industrial and utility coal-fired boilers is a practical approach for increasing renewable energy given the wide availability, existing capital investment, and established performance of coal-fired boilers for providing efficient, low cost power [1-3]. Although some utility biomass cofiring is successfully practiced in the U.S. and abroad, establishing long-term reliability and improving economics are still significant needs.

In light of the cost limitations in shipping distance (e.g., 50-100 miles or less) from collection to end-use based on the low energy density of biomass, resource availability is a site-specific consideration that needs to take into account the situation in nearby utility and industrial boilers. Table 1 provides analyses on an essentially air-dried basis to compare biomass fuels without the influence of storage conditions that can contribute to significant moisture variations. While Table 1 provides some comparisons, it should be noted that biomass fuels may exhibit considerable variability in fuel characteristics.

Table 1. Proximate and Ultimate Analyses of Various Types of Biomass Fuels (Air-Dried Basis)

| | Creosote Treated Wood | PCP-Treated Wood | Lumber Mill Sawdust | Furniture Waste Sawdust | Switch Grass | Hybrid Willow | Ground Pallets | Feedlot Manure |
|---|---|---|---|---|---|---|---|---|
| Proximate, % | | | | | | | | |
| Moisture | 5.62 | 5.01 | 5.39 | 7.88 | 8.77 | 7.83 | 4.57 | 9.98 |
| Volatile Matter | 83.54 | 88.40 | 73.55 | 75.51 | 71.68 | 75.34 | 73.58 | 40.82 |
| Fixed Carbon | 9.56 | 6.06 | 19.59 | 15.53 | 11.20 | 11.03 | 6.74 | 6.48 |
| Ash | 1.28 | 0.53 | 1.47 | 1.08 | 6.95 | 5.80 | 15.11 | 42.72 |
| Ultimate, dry % | | | | | | | | |
| Hydrogen | 6.16 | 7.28 | 6.26 | 7.09 | 6.02 | 6.02 | 4.80 | 3.13 |
| Carbon | 55.83 | 56.80 | 48.47 | 49.08 | 46.21 | 48.29 | 42.40 | 27.60 |
| Sulfur | 0.16 | 0.07 | 0.16 | 0.08 | 0.11 | 0.05 | 0.10 | 0.59 |
| Nitrogen | 0.23 | 0.18 | 0.59 | 3.25 | 0.94 | 1.20 | 0.22 | 2.40 |
| Oxygen | 36.27 | 34.29 | 42.93 | 39.16 | 39.10 | 38.15 | 36.65 | 17.64 |
| Chlorine | 0.08 | 0.82 | <0.04 | 0.17 | <0.04 | <0.04 | <0.04 | 1.20 |
| Ash | 1.35 | 0.56 | 1.56 | 1.17 | 7.62 | 6.29 | 15.83 | 47.45 |
| Btu/lb, as-rec'd | 9230 | 9434 | 7825 | 7764 | 7037 | 7077 | 6737 | 3959 |
| lb Ash/MMBtu | 1.39 | 0.56 | 1.89 | 1.39 | 11.9 | 8.25 | 22.4 | 108 |
| lb Cl/MMBtu | 0.08 | 0.83 | <0.05 | 0.20 | <0.05 | <0.05 | <0.06 | 2.73 |
| lb S/MMBtu | 0.16 | 0.17 | 0.19 | 0.10 | 0.14 | 0.07 | 0.14 | 1.34 |
| lb N/MMBtu | 0.24 | 0.07 | 0.71 | 3.86 | 0.61 | 1.57 | 0.31 | 5.46 |

In viewing Table 1, it is important to note that various biomass fuels also exhibit significant differences in ash chemistry (e.g., high alkali contents, low ash fusion temperatures) that can also influence cofiring performance, again depending on the baseline coal and boiler design/operations.

Pilot-scale biomass cofiring tests have been conducted in the 150 kWt Combustion and Environmental Research Facility (CERF). A description of the facility and some previous biomass cofiring results may be found elsewhere [4]. A key aspect of the present work is to examine biomass char conversion and transformations for a range of initial particle sizes at various residence times for combustion in comparison to full-scale utility boilers. In addition, a number of biomass cofiring R&D as well as full-scale boiler demonstration projects conducted by other organizations are providing technical insights to assist in cofiring technology commercialization. This paper will present cofiring results using a variety of biomass injection concepts, and biomass size distributions to address scalability issues.

Each of the biofuels shown in Table 1 present different opportunities and challenges for cofiring in terms of their projected range of delivered cost to utility and large industrial boilers, as well as their physical and chemical characteristics. For example, whereas most biofuels enable $NO_x$ reductions when cofiring, due to their low fuel nitrogen and high volatile matter content, there are exceptions, such as straight cofiring of high nitrogen-containing feedlot biomass where increases in $NO_x$ have been observed. However, the nitrogen compound forms of feedlot biomass suggest that lower temperature injection (such as in fuel reburn concepts) may enhance $NO_x$ reductions, although control of potential ammonia slip is important.

Because some biofuels contain significant levels of chlorine, emissions of HCl may be a barrier in cofiring, along with alkali, depending on the baseline coal and boiler operational issues. A key consideration for cofiring high-ash biofuels, such as feedlot biomass, is evaluating the impacts from slagging/fouling difficulties. For this reason, test efforts are underway in collaboration with Texas A&M University to evaluate advanced handling, and utilizing paved feedlots that incorporate coal-combustion byproducts to minimize biofuel contamination as well as reduce ambient air and groundwater impacts as compared to unpaved feedlots. Collaboration with other organizations is also underway relative to prototype mills for biomass processing and biomass/coal co-pulverization.

When considering other biofuels for cofiring, additional issues may become important, such as showing environmental acceptability in light of air toxics, including trace organics and metals. Utilities face tightening requirements, including reporting under the Toxic Release Inventory (TRI), new mercury control regulations, and looming issues in the next several years, such as ambient fine particulate $PM_{2.5}$, where multi-pollutant strategies with fuel flexibility may become increasingly important and drive R&D needs. The paper will also discuss future suggestions and research plans, including materials/corrosion and heat transfer studies, related work for biomass cofiring in advanced power systems, and tri-firing concepts with other opportunity feedstocks.

**References**

[1] Ekmann JM, Winslow JC, Smouse SM, Ramezan M. "International Survey of Cofiring Coal with Biomass and Other Wastes," *Fuel Processing Technology* 54 (1998):171-188.
[2] Tillman, DA. "Biomass Cofiring: the technology, the experience, the combustion consequences," *Biomass and Bioenergy* 19 (2000):365-384.
[3] Hughes, E. "Biomass cofiring: economics, policy, and opportunities," *Biomass and Bioenergy* 19 (2000):457-465.
[4] Freeman, M, O'Dowd, W, Goldberg, P, Plasynski, S, Walbert, G. "Pilot-Scale Cofiring Results of Treated Woods and Other Biomass Fuels for Coal-Fired Boiler Applications," Bioenergy'2000, Buffalo, NY, October 15-19, 2000.