

# Utilization of Biofuels in Boilers

## Goals

The goals of the program are to perform detailed characterizations of biofuels, develop emission factors when utilizing biofuels, and demonstrate the use of biomass materials as boiler fuels.

## Team

Participants in the EMS Energy Institute boiler biofuels program include Penn State's College of Agricultural Sciences and Office of Physical Plant, U.S. Department of Energy (DOE), Pennsylvania Energy Development Authority (PEDA), Foster Wheeler Energy and Development Corporation, Cofiring Alternatives, Allegheny Energy Supply Co. LLC, Electric Power Research Institute, SpinHeat Limited, Cargill Taylor Meats, Hatfield Quality Meats, and the National Cattlemen's Beef Association.

## Program Discussion

Penn State is developing technologies to retrofit boilers, gaining expertise in integrating hardware to achieve fuel flexibility in boilers, and generating a database of fundamental pyrolysis, combustion, and ash chemistry interactions of biofuels. Penn State is working with industry to evaluate nontraditional fuels – e.g., animal wastes, rendered products, woody and herbaceous by-products, animal-tissue biomass (ATB), RDF pellets – fuels that are being considered to replace natural gas and fuel oils in boilers due to the demonstrated price volatility associated with the gas and fuel oils. Biofuels are being evaluated for use in both industrial and utility boilers and, depending on the fuel characteristics, in watertube, firetube, and fluidized-bed boilers.



Hatfield Finished Lard



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## Background

For nearly two decades, the EMS Energy Institute at Penn State has been actively involved in industrial boiler research and development with an emphasis on multifuel capabilities, hardware development and testing, fuels evaluation, and emissions characterization and reduction. The multiple fuel concept can be applied to: existing boilers modified to fire several fuels simultaneously; fuel switching in existing boilers; and newly installed boilers designed with multiple fuel capabilities.

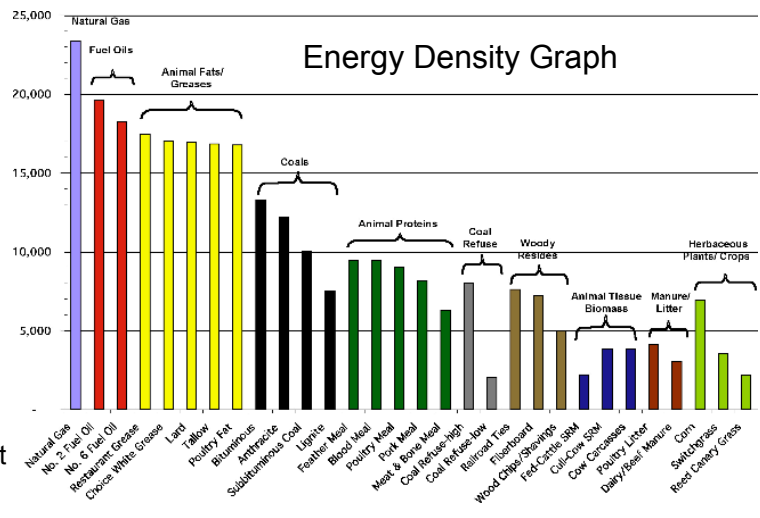
Historically, the emphasis has been on 'multi-fossil fuel' capabilities (e.g., cofire a coal-water slurry mixture with pulverized coal), which has now evolved into the utilization of agricultural by-products in industrial boilers designed for fossil fuels as well as newly-designed boilers capable of cofiring coal and biofuels. The use of agricultural by-products allows the industrial boiler operator to reduce energy (fuel) costs, utilize a waste product, obtain fuel flexibility, and use indigenous resources (i.e., home-grown fuels). The fuels of interest include animal fats/ vegetable oils, animal proteins, ATB, manure/ litter, grasses/ crop residues, waste wood products, food processing wastes, and waste seeds. The EMS Energy Institute has been working with various companies including those from the meat packing, rendering, and feed industries, project developers, boiler manufacturers, as well as DOE and PEDA, in evaluating these potential feedstocks as boiler fuels. In addition, Penn State performed a feasibility analysis to install a circulating fluidized bed boiler at the University Park campus to cofire coal and a variety of biofuels. Activities in this program area include: fundamental studies through bench and pilot-scale testing; full-scale demonstrations; and system designs and feasibility studies. Testing has focused primarily on feedstock evaluations, combustion testing, and emissions characterizations in industrial watertube and fluidized-bed boilers.

## Results

The EMS Energy Institute has an ongoing program to characterize and combust biomass to determine its viability as a fuel when fired individually or in cofiring applications. Characterization includes: chemical and physical properties, analysis of solid and liquid biomass streams, kinetics of pyrolysis and char oxidation, thermochemical modeling of inorganic constituents, bench-scale testing, and pilot-scale evaluations. Examples of projects are summarized herein.

A detailed fuel characterization study was performed for Foster Wheeler Development Corporation as an element of the test program for the Willow Island Generating Station sawdust cofiring demonstration (Allegheny Energy Supply Co., LLC) and to provide insights into the results experienced by Southern Company at the Plant Gadsden switchgrass cofiring test. Characterization studies included determining fuel structure, maximum volatile yield, evolution of volatile nitrogen species relative to volatile carbon species, devolatilization kinetics, and chemical kinetics of char oxidation.

Animal fats, proteins, and tissue are being evaluated as industrial boiler fuels through fuel characterization, handling studies, and combustion and emissions testing. Candidate boiler fuels studied include choice white grease, lard, poultry fat, yellow grease, tallow and tallow by-products, blood meal, feather meal, meat and bone meal, poultry meal, pork meal, cow carcasses, and SRMs. Participants in this work include Hatfield Quality Meats, Cargill Taylor Meats, and the National Cattlemen's Beef Association. (The tissue work is discussed in a separate fact sheet. The combustion and emissions performance when burning animal wastes are evaluated using a fluidized bed combustor. For example,



poultry litter has been tested in a fluidized-bed combustor for SpinHeat Limited, LLC and DOE. Consequently, the installation of a fluidized bed boiler is planned for the Delmarva Peninsula.

Penn State, in conjunction with DOE, performed a feasibility analysis on installing a state-of-the-art circulating fluidized-bed boiler at Penn State's University Park campus for cofiring multiple biofuels with coal, and developing a test program to evaluate cofiring multiple biofuels and coal-based feedstocks. As part of the resource characterization, the types and quantities of potential feedstocks were assessed. Approximately twenty different biomass, animal wastes, and other wastes were identified, collected, and analyzed. These potential feedstocks include the following: animal wastes such as dairy tie-stall and free-stall manure (mixed with leaves and brush to make it stackable), beef manure, horse manure, poultry litter, sheep manure, and swine waste; woodwaste and brush; Reed Canary grass; bottom and fly ash from the University's stoker boilers; agricultural plastics; wood shavings and chips from the surrounding region; and sewage sludge. The feasibility study has been completed and is currently being evaluated as an option in the development of Penn State's 20-year Master Energy Plan.

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### Key Publications

- Miller, B. G., S. Falcone Miller, R. T. Wincek, and R. S. Wasco, "Fuel Flexibility in Boilers for Fuel Cost Reduction and Enhanced Food Supply Security Final Report," Prepared for Pennsylvania Energy Development Authority, Agreement No. PG050020, June 30, 2006, 509 pages.
- Falcone Miller, S., and B.G. Miller, "The Effect of Cofiring Coal and Biomass on Utilization of Coal Combustion Products: The U.S. Perspective," *11<sup>th</sup> International Conference on Ashes from Power Generation*, Zakopane, Poland, October 13-16, 2004.
- Miller, B.G. and S. Falcone Miller, "Utilizing Biomass in Industrial Boilers: The Role of Biomass and Industrial Boilers in Providing Energy/National Security," *The First CIBO Industrial Renewable Energy & Biomass Conference*, Minneapolis, Minnesota, April 7-9, 2003.
- Miller, B. G., S. Falcone Miller, R. E. Cooper, Jr., N. Raskin, and J. J. Battista, "Biomass Cofiring: A Feasibility Study for Cofiring Agricultural and Other Wastes with Coal at Penn State University," *27th International Technical Conference on Coal Utilization & Fuel Systems*, Clearwater, Florida, March 4-7, 2002.
- Falcone Miller, S., B. G. Miller, and D. Tillman, "The Propensity of Liquid Phases Forming During Coal-Opportunity Fuel (Biomass) Cofiring as a Function of Ash Chemistry and Temperature," *27th International Technical Conference on Coal Utilization & Fuel Systems*, Clearwater, Florida, March 4-7, 2002.