



Biomass Utilization in Stationary Heat & Power Systems: RD&D Activities at Penn State's Energy Institute

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ENERGY INSTITUTE

COLLEGE OF EARTH AND
MINERAL SCIENCES



Presentation Outline

- Summary of the Energy Institute's technical areas of expertise (focusing on stationary combustion)
- Examples of biomass characterized/ tested
- Overview of the Energy Institute's biomass combustion activities
- Selected results from biomass combustion & emissions testing
- Examples of companies/ agencies we work with



Technical Areas of Biomass Stationary Combustion Expertise

- Resource assessments
- Fuels evaluation (fundamental and applied behavior in combustion systems) and characterization
- Emissions characterization and control
- Fundamental behavior of inorganic elements
- Analytical techniques for characterizing inorganic phases in fuels and combustion byproducts
- Statistical techniques for designing engineering experiments and evaluating data

Examples of Biomass Feedstocks (Woody and Herbaceous Biomass)

- Wood residues, herbaceous plants, and crops
 - Sawdust/ wood chips/ road clearings
 - Urban wood waste
 - Tree-of-Heaven
 - Grasses -- Switchgrass (aged and fresh), Reed Canary Grass
 - Corn/ soybeans

Total forest resources - 368 MDT/yr

Total agricultural residues - 159-954 MDT/yr

From USDA/U.S. DOE Feedstock Report 2005



Examples of Biomass Feedstocks (Manure and Litter)

- Manures
 - Poultry litter
 - Dairy/ beef manure
 - Swine wastes
 - Sheep manure
 - Horse manure

Manures - 35-44 MDT/yr

From USDA/U.S. DOE Feedstock Report 2005



Poultry Litter



Dairy Manure

Examples of Biomass Feedstocks (Animal Fats and Greases)

- Animal fats/ vegetable oils
 - Choice white grease/ lard
 - Tallow
 - Poultry fat
 - Restaurant grease
 - Soybean oil
 - Coconut oil



Fats (excluding oils) - 11.6 B lb/yr

From Fats and Proteins Research Foundation, Inc. 2005

Examples of Biomass Feedstocks (Animal Proteins)

- Animal proteins
 - Feather meal
 - Blood meal
 - Poultry meal
 - Pork meal
 - Meat & bone meal

Pork Meal



Proteins - 9.2 B lb/yr

From Fats and Proteins Research Foundation, Inc. 2005

Meat & Bone Meal

Examples of Biomass Feedstocks (Animal-Tissue Biomass)

- Animal-Tissue Biomass (ATB)
 - Raw or pre-processed animal-derived tissues
 - Animal parts such as specified risk materials (SRMs)
 - Whole animals including beef/dairy cow carcasses, poultry, cervids
 - Meat processing wastes that are not desired in animal feed products
 - Emergency slaughter carcasses

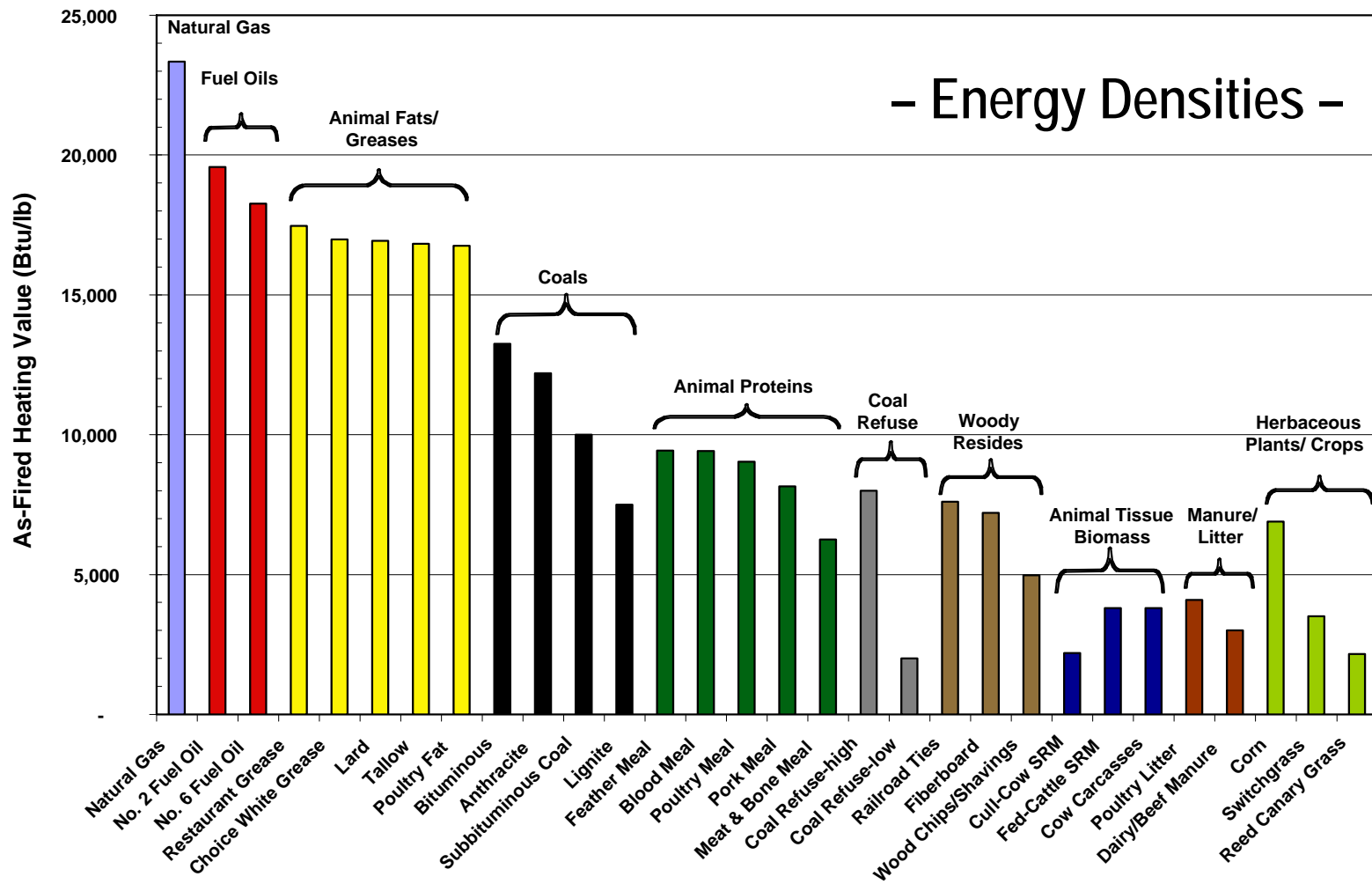


ATB >6 B lb/yr

From Sparks 2002; Harlan 2004

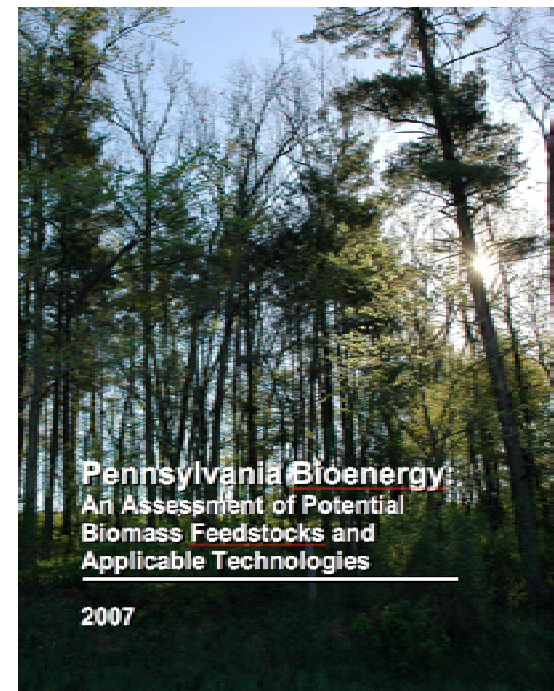
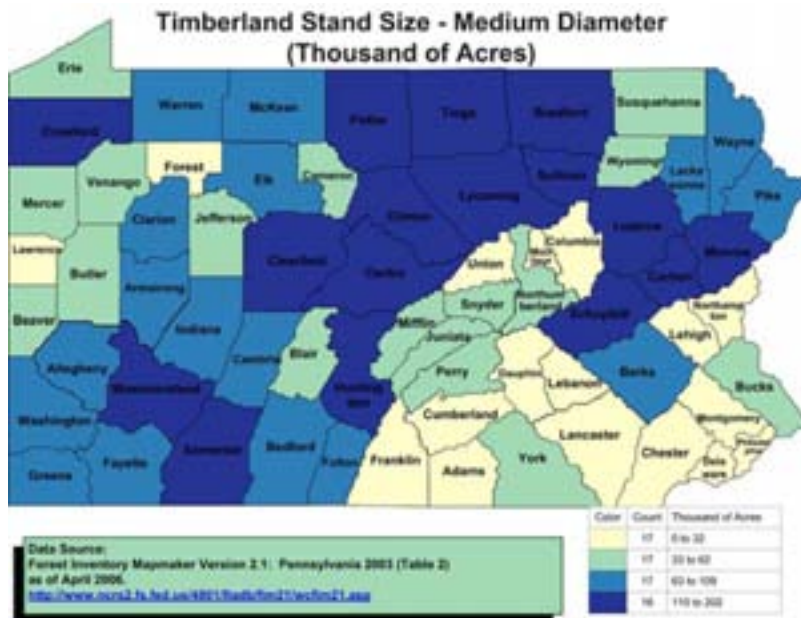
*Ground/chipped
cattle carcasses*

Comparison of Various Boiler Fuels Tested at the Energy Institute



Resource Assessments

- Local (University Park)
 - 45 and 100 mile radius
 - As part of a study on the feasibility of installing a CFB on campus to cofire biomass and coal
- Statewide

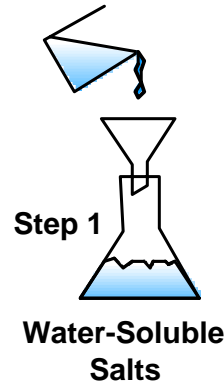


Fuel Characterization

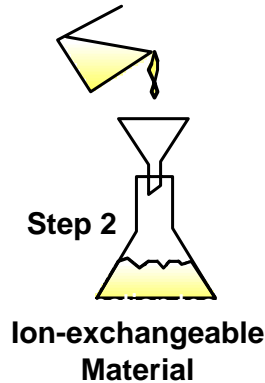
- Advanced Fuel Analysis

- Fundamental combustion/ pyrolysis kinetics
- Fundamental nitrogen and volatile matter evolution studies for burner design and NO_x control
- Chemical fractionation to assess behavior of inorganics
- Fuel structure

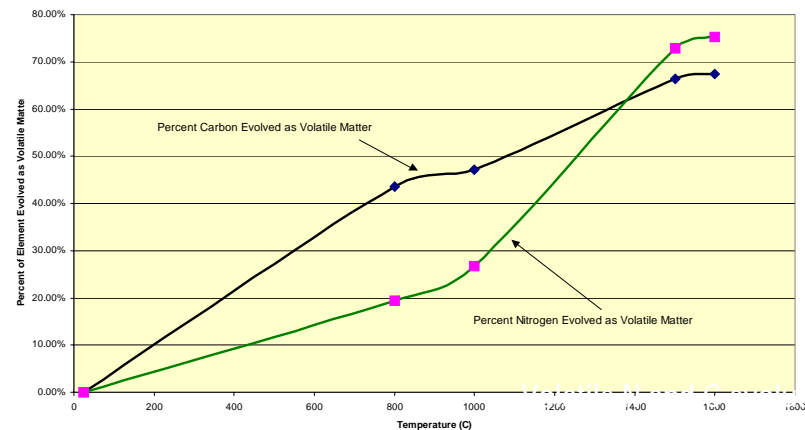
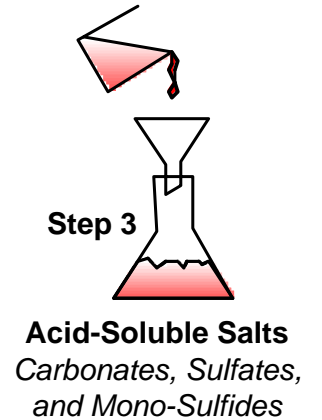
Deionized Water
Leaches raw fuel



Ammonium Acetate (1M)
Leaches residue from Step 1



Hydrochloric Acid (1M)
Leaches residue from Step 2

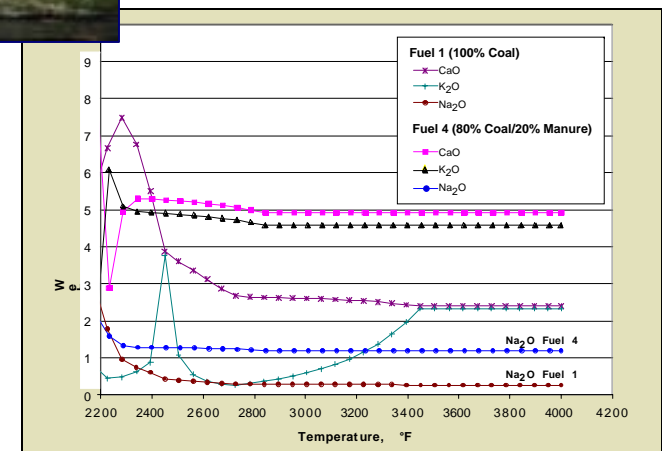
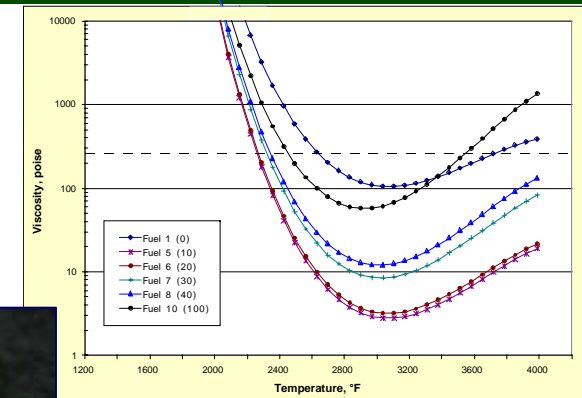


Fundamental Behavior of Inorganic Elements

- Application of thermodynamic modeling (ChemSage, FACTWin, FACTSage) to predict ash deposition and agglomeration, particle formation, and emissions
- Characterization of trace elements in flue gas
- Relating the occurrence, size, and composition of inorganics in biomass to ash formation, partitioning of inorganic elements during combustion, and physical properties of ash and slag formed



*FBC bed
agglomeration*



Combustion Test Units

- Bench-scale drop-tube reactor
- Residential corn furnace
- Residential pellet stove

Residential pellet stove testing switchgrass pellets



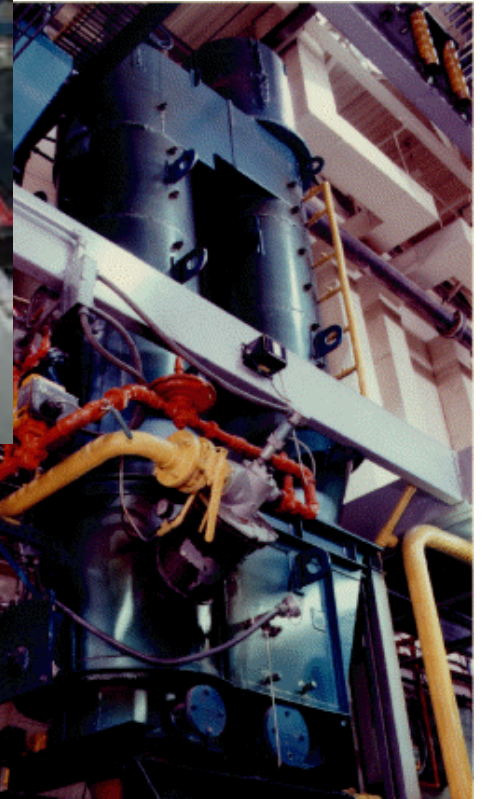
Residential corn stove



Drop-tube reactor

Combustion Test Units

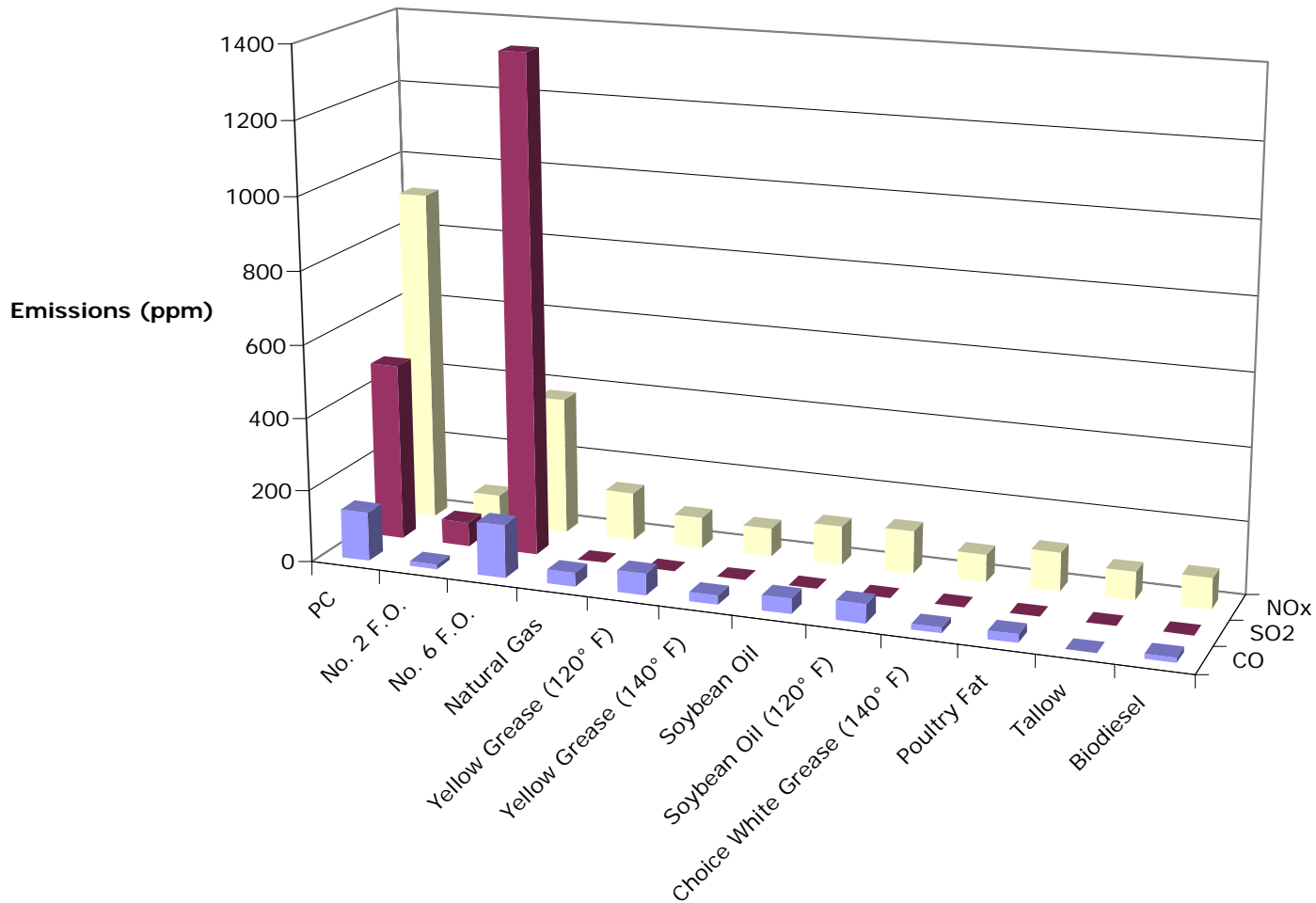
- Commercial watertube boiler
- Pilot-scale fluidized-bed combustor



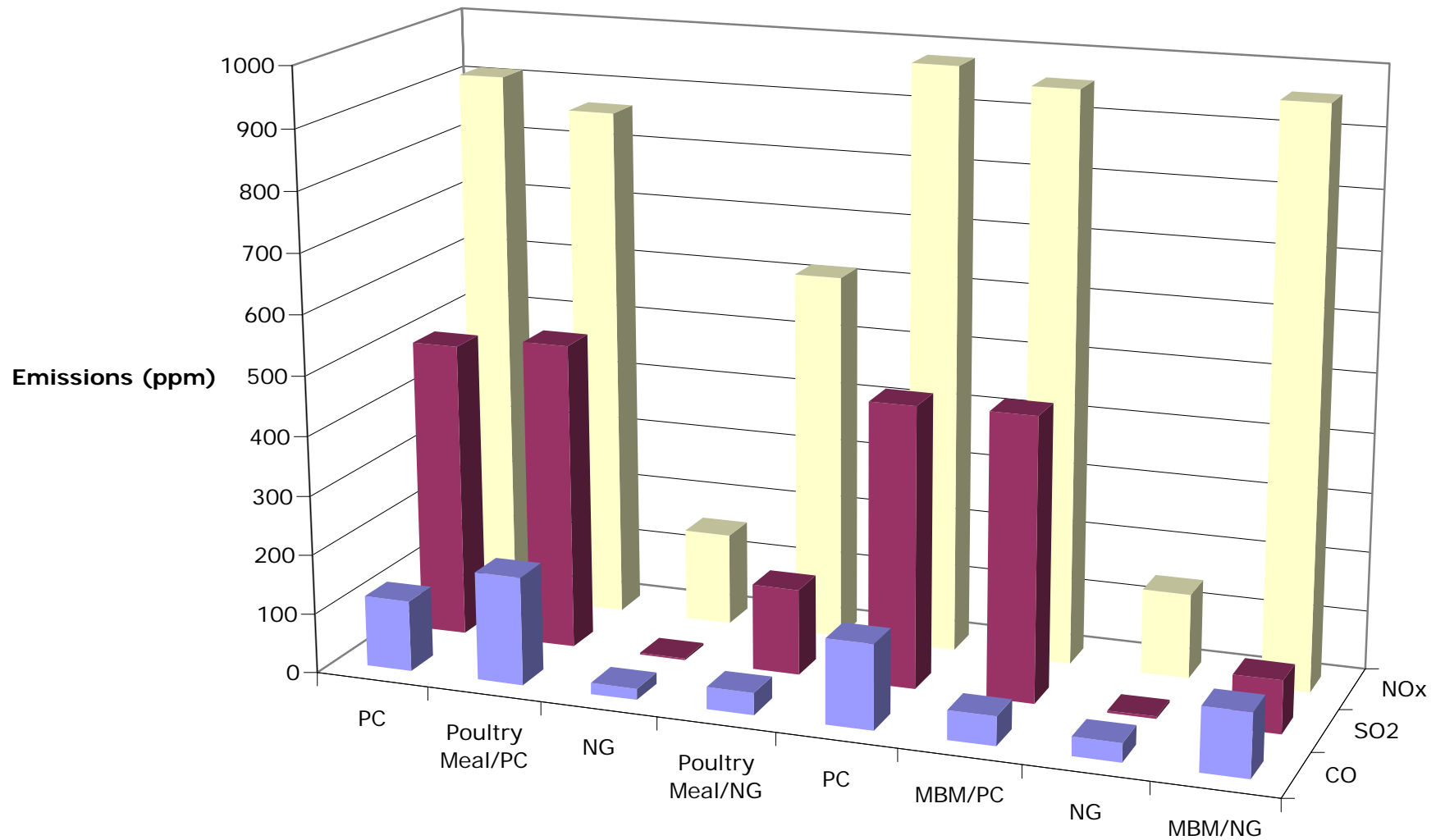
Oil-Designed Watertube Boiler Firing Lard

*FBC Firing
Animal-Tissue
Biomass*

Emissions Characterization and Emissions Factor Development (from Watertube Boiler Testing)



Emissions Characterization & Food Security Assessments





Examples of Recent Research Supporters

- Federal Agencies
 - U.S. Department of Energy
- State Agencies
 - SUNY Syracuse
 - Penn State Office of Physical Plant
 - Pennsylvania Energy Development Authority
- Industry
 - Cargill Meats Solutions
 - National Cattlemen's Beef Association
 - Foster Wheeler
 - Oilmatic International, LLC
 - Hatfield Quality Meats
 - Keystone Protein Company
 - Soy Energy, LLC
 - Monona Farms