Development of a validated model for use in minimizing NO_X emissions and maximizing carbon utilization when cofiring biomass with coal

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This project will produce a validated predictive model to optimize the cofiring of biomass and coal to minimize NO_X emissions and maximize carbon utilization. The effect of biomass cofiring on NO_X emissions has been site-specific and so limited that there is no basis to specify fuel or injection system characteristics to minimize the formation of NO_X. This project is designed to fill a void in the understanding of the interactions of biomass and pulverized coal with guidance, in the form of a predictive model that enables optimal energy and environmental benefits from cofiring these two types of fuel. The computer model, based on EPRI's NO_X LOI Predictor that Niksa Energy Associates and others successfully developed for coal-fired boilers, will (i) identify the biomass cofiring injection configuration that minimizes NO_X emissions in flames of biomass/coal blends; and (ii) predict the NO_X reduction efficiency and loss-on-ignition (LOI) of biomass cofiring. Project partners include Southern Research Institute, Southern Company Services, Niksa Energy Associates, Reaction Engineering International, and General*Bioenergy, Inc.

The computer model will be validated through an extensive set of tests at the 6 MBtu/hr pilot combustor in the Southern Company Services/Southern Research Institute Combustion Research Facility (SCS-SRI CRF). Tests will cover a broad range of biomass materials, coal types, fuel mixing conditions, and combustor configurations. These parameters will be evaluated in controlled tests at a scale that has been demonstrated to conform to the emissions profiles from full-scale utility boilers. The scalable database will have inherent value as a reference set of data for the impact of biomass cofiring on NO_X emissions. Moreover, this characterization will be considerably strengthened by the connections between the pilot-scale tests and the detailed process model that will be developed in tandem with the testing. For this investigation, the SCS-SRI CRF will be fired at 3.6 MBtu/hr to emulate the time-temperature profile of a typical pulverized coal-fired boiler in the Southern Company system.

Model predictions will be validated across the entire laboratory database to within useful quantitative tolerances. Once validated, the model will provide a relatively inexpensive means either (1) to identify the most effective cofiring injection configuration for specified compositions of biomass and coal within a particular furnace environment, or (2) to forecast the emissions for a specified pair of fuels fired under an existing configuration. As such an important cost-saving tool, the modeling has the potential to accelerate widespread adoption of biomass cofiring as a NO_X control strategy in the electric utility industry.

The test matrix contemplated for this work includes four types of coal (Powder River Basin, Eastern bituminous low-sulfur, Eastern bituminous high sulfur, and Illinois Basin coals). Two burner configurations are to be tested (single register tangential burner and generic low-NO_X dual-register burner). Five schemes for biomass injection with either burner will be tested (burner alone, biomass comilled with coal, separate biomass injection through the center of the burner, off-axis direct injection into the flame, and off-axis direct injection parallel to the flame). Eight candidate sources of biomass have been identified that cover a range of fuel nitrogen of which up to six will be selected for testing (switchgrass, poultry litter, coastal Bermuda grass, wet and dry hardwood sawdust, willow, hybrid poplar, and rice straw). Finally, three levels of biomass addition are planned, as a percentage of the total mass fired (0%, 10%, and 20%).
Each test condition requires one full day of testing at the SCS-SRI CRF. During that day, with a particular fuel and burner configuration, the furnace will be operated at three levels of furnace exit

oxygen (usually 2.5%, 3.5%, and 4.5%) at up to two levels of overfire air (usually 0% and 15%). At each level of furnace exit oxygen and overfire air, gaseous and particulate emissions and furnace operating parameters are measured and recorded. Thus, within one week of testing, a maximum of five test conditions can be performed.

Eighteen separate week-long tests are planned, two of which have been completed. As testing proceeds, and the database of test results is compiled, the results of modeling will be compared with the test results obtained to verify and tune the model.

Initial test results with dry hardwood sawdust cofired with Pratt seam coal suggest that significant NO_X reductions are possible. Preliminary results also suggest that concomitant increases in combustion efficiency (reduction of unburned carbon) were also realized, however the measurements required to quantify these data are not yet complete. Two biomass injection schemes have been tested to date. These include direct mixing of biomass with coal (up to 20% by mass) and biomass injection concentrically through the center of the burner (up to 10% by mass).

In terms of NO_X emissions, at 3.5% furnace exit oxygen and 15% overfire air, referred to dry flue gas at 3% O_2, NO_X emissions averaged 335 ppmv for 100% Pratt seam coal. For hardwood sawdust comilled with Pratt seam coal, NO_X emissions were reduced by 18% when 10% of the coal was replaced by hardwood sawdust and by 24% when 20% of the coal was replaced by sawdust. On the other hand, when the same sawdust was injected concentrically through the center of the burner, at a level of 10% addition, NO_X emissions were reduced by only 8%.

Clearly, NO_X emissions are a function of many independent variables. It is the goal of this project to develop and verify a computational model that reliably predicts the reduction of NO_X emissions possible through biomass cofiring with coal. This project is being carried out under DOE Cooperative Agreement DE-FC26-00NT40895, through the U.S. Department of Energy, National Energy Technology Laboratory, in Pittsburgh PA. The DOE Project Officer is Mr. Sean Plasynski.