Title Minimizing Net CO_2 Emissions by Oxidative Co-Pyrolysis of Coal/Biomass Blends

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ABSTRACT

Increasing concern over global climate change is motivating a technical reassessment of the current modes of fuel use in the United States. Solid fuels vary significantly with respect to the amount of CO_2 directly produced per unit heating value, due to the combined effects of varying enthalpy and carbon weight percentages. Elemental carbon is notably worse than other solid fuels in this regard, and since carbon (char) is an intermediate product of the combustion of almost all solid fuels, there is an opportunity to reduce specific CO_2 emissions by reconfiguring processes to avoid char combustion wholly or in part. The intentional partial combustion of coal has several practical disadvantages, however. Partial combustion creates large quantities of unburned carbon, which renders the fly ash unsuitable as an admixture in concrete, where it serves as a cement substitute [Freeman et al., 1997]. Avoiding cement manufacture reduces net CO_2 emissions in two ways: it reduces fuel use in the kiln and it avoids CO_2 emissions associated with limestone calcination. Intentional partial combustion of coal can also cause problems with electrostatic precipitator operation due to high-carbon fly ash. An intriguing alternative is the oxidative pyrolysis of biomass carried out in conjunction with traditional coal combustion, as described below.

Large quantities of CO_2 (388 Gigatons / yr) are released each year due to the natural respiration and decay of biomass in forests, agricultural applications, and landfills [Klass, 1998]. Combustion of waste biomass fuels (e.g. wood, paper, agricultural residues) leads to decreases in real CO_2 emission, because the alternative is coal combustion plus natural biological degradation of the biomass carbon to CO_2. Further, if biomass degradation is partially anaerobic, some of the carbon is converted to CH_4 (an even more potent greenhouse gas) and there is even more motivation to burn biomass fuels and avoid natural decay. The co-firing of biomass and coal in existing coal-fired boilers has received much attention as a promising option for reducing net CO_2 emissions. Co-firing combines the advantages of biomass (reduced net CO_2 emissions) with the advantages of coal (stable operation, high efficiency, and favorable economics of large coal-fired power plants). The single most important hurdle to expanded use of biomass in co-firing is the distributed nature of the source and its low volumetric energy density, making handling, processing, and transport to centralized power generating facilities expensive. The arguments for partial combustion can also be applied to biomass, so CO2 offsets from

cofiring can be further enhanced by leaving a portion of the biomass char unburned. such an oxidative pyrolysis process may be especially advantageous if it can be carried out in a way the does not perturb the coal combustion subprocesses with their high efficiency, well-developed environmental controls, and byproduct utilization.

Other authors have proposed the straight carbonization of biomass residues to sequester carbon in its stable elemental form [Bilger, 1999]. Although this process does not produce heat, it the associated carbon storage credits can have a significant positive impact on CO_2 emissions, while not necessarily requiring transportation of the voluminous biomass to large, central power stations. A primary goal of the current project is to make a fundamental thermodynamic assessment of these various modes of solid fuel use.

In the first 8 months of this Innovative Concepts project, we have carried out thermodynamic calculations on a large set of traditional and alternative fuels to establish the ultimate constraints on the CO_2 emissions during (a) combustion, (b) carbonization (with no heat export), (c) oxidative pyrolysis. The full set of calculations were done for a matrix of cases considering:

- wet vs. dry utilization
- ASTM volatile yields vs. true chemical equilibrium in the pyrolysis step
- incremental utilization of alternative fuels in one of two traditional fossil-fuel environments: one in which baseline energy is currently provided by combustion of high-volatile bituminous coal, and one based on natural gas.

The calculations show very clear trends with fuel type, process type (combustion / carbonization / oxypyrolysis), and with the baseline fossil-fuel environment in which the alternate fuel utilization takes place. Of particular interest are the calculations involving biomass. In a baseline coal environment, biomass cofiring is much more beneficial than straight carbonization. Oxidative pyrolysis gives slightly higher CO_2 offsets, but likely not enough to warrant the additional process complexity. In a baseline natural gas environment, where the alternative fuel use displaces gas, the two options involving elemental carbon storage (carbonization and oxypyrolysis) begin to look more attractive. On a thermal basis, simple carbonization provides 80% of the CO_2 offset achievable by biomass combustion, while oxidative pyrolysis produces a 40% <u>larger</u> CO_2 offset than biomass combustion. The effects are largest when the energy product is electricity. In a baseline gas environemnt, accounting for the higher efficiency of gas-fired plants relative to dedicated biomass-only systems, both straight carbonization and oxydative pyrolysis give much larger CO_2 offsets than traditional biomass carbonization — a very interesting result.

LITERATURE REFERENCES

Bilger, R.W. "The Future for Energy from Combustion of Fossil Fuels", *Fifth International Conference on Technologies and Combustion for a Clean Environment*, Lisbon, Portugal, pp. 617-623, 1999.

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This Innovative Concepts project has been active only 8 months, and prior to the UCR review meeting as there have been no publications or presentations. A publication on this topic is planned, with the tentative goal of submission at the end of the summer of 2001, at about the same time as final report preparation. This grant has provided support for Ph.D. student Todd Lang in the Division of Engineering at Brown University.