NABC National Advanced Biofuels Consortium
Biofuels for Advancing America
Developing cost-competitive, sustainable biofuels for today's transportation infrastructure.

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RTI International's Bench-Scale Hydropyrolysis Studies as Part of NABC

Direct liquefaction pathways for converting biomass into liquid transportation fuels have been investigated for a number of years. Traditional biomass flash pyrolysis processes have demonstrated a roughly 70% liquid product yield; however, this pyrolysis oil product has limited use without additional upgrading or refining. The chemical and physical properties of bio-oil limit the application of this material as a transportation fuel, for distributed power generation, and as a chemical feedstock. The high oxygen content and low pH of bio-oils limits their miscibility with petroleum refining streams and decreases their thermal stability and compatibility with petroleum refining technology.

Using catalysts to improve the physical and chemical properties of bio-oils is currently an active area of research, development, and demonstration. The role of the catalyst is to control the chemistry during biomass pyrolysis to minimize carbon loss to char, light gases, and coke and control deoxygenation. Oxygen removal can occur by dehydration (loss of H_2O), decarboxylation (loss of CO_2), and decarbonylation (loss of CO).

Biomass hydropyrolysis combines biomass, catalyst, and hydrogen in a single step at modest temperature and pressure to produce a hydrocarbon-rich liquid intermediate that can be upgraded into an advanced biofuel using conventional petroleum refining technology. Commercially-available hydroprocessing catalysts can be used in this direct approach to maximize hydrodeoxygenation and improve hydrogen utilization to produce a low oxygen content bio-crude intermediate.

The goal of the Hydropyrolysis (HYP) Strategy Area is to develop a technically viable and economically feasible process to convert biomass into a hydrocarbon-rich bio-crude. The major technical barriers were identified in Stage 1 and are being addressed in an integrated Stage 2 R&D plan. The Stage 2 experimental objectives include optimizing product yield and quality, determining equilibrium catalyst performance, and quantifying hydrogen demand for biomass hydropyrolysis with selected catalysts at a range of process conditions.

A new bench-scale hydropyrolysis reactor system was designed and fabricated by RTI to better understand the physical and chemical properties of the bio-crude as a function of catalyst, hydrogen partial pressure, and temperature. The new high pressure, high temperature fluidized bed reactor system (shown in Figure 1) provides a number of operational advantages that have increased the throughput of the system, increased the amount of data that can be collected, and improved data quality.

These advantages include:

- Expanded catalyst testing
- Improved liquid collection and better mass balance
- Direct measurement of hydrogen consumption

- Endothermic/exothermic reaction trends
- Increased liquid output
- Increased biomass/catalyst ratio

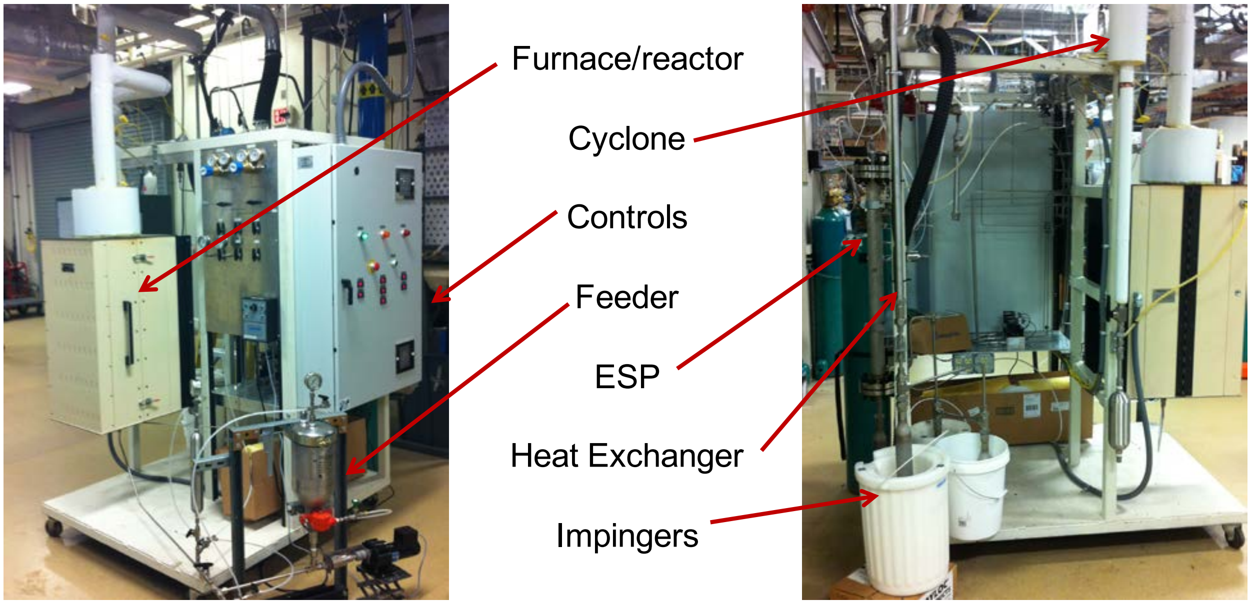

Figure 1. RTI International's Bench-scale Hydropyrolysis Reactor System

Parametric hydropyrolysis testing with the most promising catalyst identified in Stage 1 was conducted at a range of temperatures (375°–475°C), pressures (150 psig and 300 psig), and hydrogen partial pressures (20% and 40%) with the loblolly pine feedstock. Product distributions were measured for the process conditions tested with mass closures routinely >90%. Increasing process severity (temperature and hydrogen partial pressure) produced desired organic liquid bio-crude products with lower oxygen content and increased aliphatic concentration. These bio-crude property improvements, however, must be balanced against carbon losses to increased gas yields with higher temperatures.

The oxygen content of the bio-crude ranged from 0.5 to 6 wt% with the lower oxygen content. At the most severe conditions—450°C and 40% H_2 at 300 psig—the bio-crude oxygen content was ~0.5 wt%. A large (1.5 L) sample of this bio-crude was produced for comprehensive analysis by the Refinery Integration Team.

The results from the recent bench-scale biomass hydropyrolysis experiments have shown promising progress toward the targeted goals for economic viability of the process. These improvements include an increase of over 50% toward the targeted yield values, while lowering the oxygen content of the product oil to a value attractive for refinery integration. These updates have been incorporated into techno-economic models and the advances are reflected in an overall reduction of the minimum fuel selling price. Additional efforts to improve the techno-economic models have focused on optimizing operating/design conditions, improving capital costs, and optimizing hydrogen management and heat integration for various commercial design concepts.