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

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Hydrothermal Liquefaction – Results from Stage I Extension

The National Advanced Biofuels Consortium (NABC) is developing improved methods for producing high value hydrocarbon fuels. In August, the NABC evaluated results from six Stage I technology strategies and selected two "drop-in" biofuels technology pathways that will be advanced to pilot ready status in Stage II. During the selection, the high carbon yields and desirable biofuel product distribution from hydrothermal liquefaction (HTL) (Figure 1) were recognized; however, questions remained on how the process would be scaled to pilot or production scale. Therefore, the HTL team was given an additional three months to identify the pathway to pilot readiness. In this highlight we report on the two technical aspects of the extension research: 1) identifying commercially available pumping systems suitable for a production scale plant and 2) demonstrating HTL in a plug flow reactor (PFR), consistent with the technoeconomic analysis.

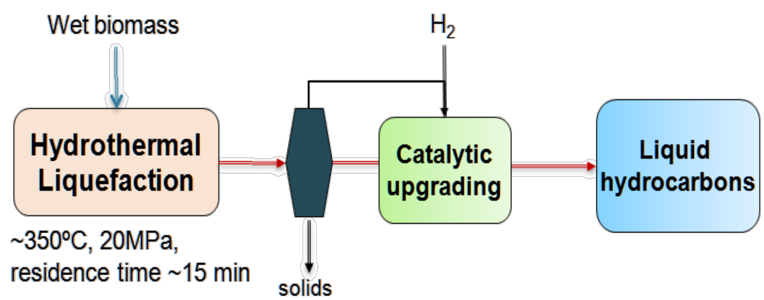

Figure 1. Overview of HTL strategy

The HTL process strategy is being developed within NABC by Andy Schmidt and Doug Elliott at Pacific Northwest National Laboratory (PNNL). In the HTL process this conversion is done with wet biomass at elevated temperatures (300°–360°C, or 570°–680°F) and the pressure is maintained above the vapor pressure of water (15–20 MPa or 2,200–3,000 psi at these temperatures) to facilitate a condensed phase reaction medium. During Stage I, bio-oil yields of about 50% on a carbon basis were achieved via HTL from both NABC feedstocks (woody final harvest residuals and corn stover) in continuous testing with a 1-L bench-scale, continuous-stirred tank reactor (CSTR). The resulting bio-oil was readily upgraded to a hydrocarbon product consistent with gasoline and diesel.

Pumpability Evaluation

Based on the technoecnomic analysis for the production plant, a pumping requirements document was assembled and provided to a number of prospective pump vendors. Rheological testing, including flowability/slump testing (Figure 2) was conducted to assist vendors in the determination of the suitability of their pumps to the 2,000 dry metric tons per day production rate (2,300 gallons per minute at 15 wt% and 3,000 psi).

From this evaluation, five vendors responded with four pump types (positive displacement, hydraulic membrane, hose diaphragm, and rotary lobe). Relevant production models were identified, and budgetary quotes were provided for pilot and production plant feeding and pumping systems. Vendors were confident that the flowable immersion milled slurry could be pumped (Figure 2, left); however, testing will be necessary to determine the pumpability limits of feed material with little or no slump (Figure 2, right).

Figure 2. Slump-testing, immersion milled pine (left), 4 inch slump, and hammer milled corn stover (right), zero slump

Plug flow reactor testing

A series of tests were conducted to evaluate oil production and yields in a PFR system. PFR systems are scalable, cost less, are more volume efficient, and mechanically simple compared to CSTR systems. For the PFR testing, a feed slurry is pressurized and passed through a heated tube/pipe, product is filtered, accumulated, and pressure is let down on the gas phase (Figure 3). In Stage I testing, liquid hourly space velocities up to 1.5 L/L/h were demonstrated with the CSTR. During the Stage I extension, space velocities in the range of 1 to 25 were tested in the PFR. The bio-oil yield, bio-oil composition, and aqueous product composition from the PFR were similar to those in the CSTR tests. However, the physical properties of the bio-oil (e.g., density and viscosity) differed in the PFR tests suggesting optimal conditions were not yet met. Also, while the plug flow reactor was successfully demonstrated, reactor plugging issues in the heat up zone limited the run times and created material balance closure issues.

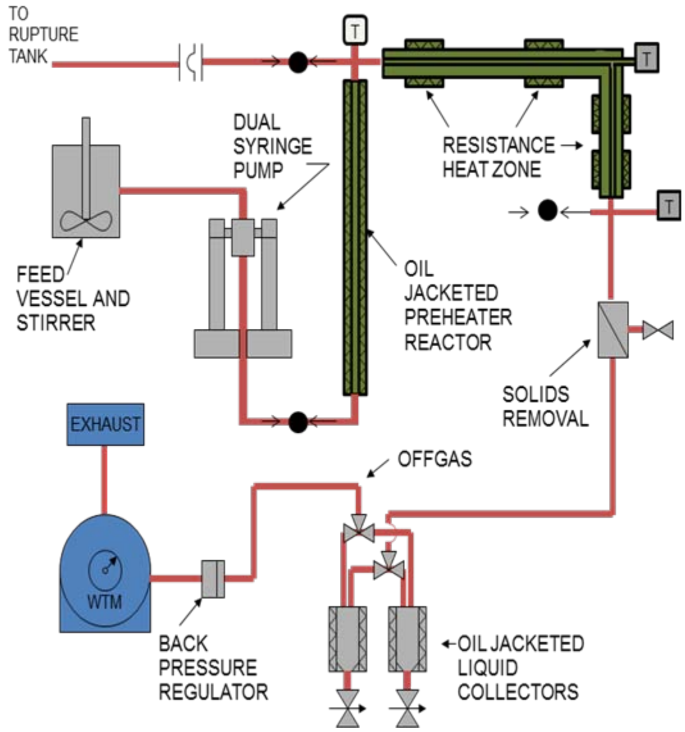

Figure 3. Process flow schematic of plug flow reactor system

During the Stage I extension the HTL team 1) identified commercially feasible systems and vendors that have the ability to pump high solids biomass feed streams to 3,000 psi, and 2) provided experimental evidence for the plug-flow reactor configuration operating at industrially relevant conditions. Optimizing the PFR system will be the primary focus in future HTL research and development. This will allow the HTL team to achieve shown promise of producing high yields of stable oils with what we believe will be low capital and operating costs.