Co-conversion of coal with some biomass to liquid fuels can help to reduce CO2 emissions because of the neutrality of biomass with respect to CO2 emissions. An NETL study [Affordable, low cost diesel fuel from domestic coal and biomass, DOE/NETL2009/1349, January 2009], in fact, has indicated that addition of even moderate amounts of biomass to coal for the production of liquids can potentially reduce Life Cycle Analysis (LCA) CO2 emissions relative to petroleum diesel baseline; for example, 20% less CO2 is produced with 8% biomass addition, with Carbon Capture, Storage, and Utilization (CCUS).

Fischer-Tropsch synthesis (FTS) is a leading technology for converting syngas from gasification to hydrocarbons in coal to liquids (CTL) and coal-biomass to liquids (CBTL) processes. However, conventional FT catalysts produce undesirable waxes (C21+) that need to be upgraded to liquids (C5-C20) by hydrotreating. This adds significantly to the cost of FTS.

Development and commercialization of a cost-effective gasification/FTS-based CBTL process to produce renewable gasoline and diesel can reduce the nation’s dependency on oil imported from foreign countries, help to stabilize the prices at the pump, and lower the emission of greenhouse gases.
Small-Scale Coal-Biomass to Liquids Production Using Highly Selective Fischer-Tropsch Synthesis

Project Description

The use of domestic coal resources can be a significant primary energy source for liquid fuel production, and the addition of biomass to coal at moderate levels has the potential to reduce the carbon footprint of coal-biomass-to-liquid (CBTL) processes to levels below petroleum based fuel production processes. This project demonstrated a novel liquid-fuel selective FT catalyst and heat exchange reactor technology for the economical, environmentally-sustainable, and highly selective conversion of coal-derived and coal-biomass-derived syngas to gasoline and diesel range hydrocarbons (C5-C20). Southern Research worked with Chevron (selective catalyst supplier) and NCCC (host site) to design and run a bench-scale skid-mounted FT reactor system for selective FT conversion of coal- and coal-biomass derived syngas using a slip-stream from the gasifier at NCCC. The project included gasifying coal and coal-biomass feed blends using a demonstration scale coal gasification system at the NCCC. A slip stream of the produced syngas was fed to the bench scale FT reactor containing the novel selective FT catalyst to produce predominantly C5 to C20 gasoline and diesel range hydrocarbons liquids. The skid included extensive gas cleanup operations, and sampling and analytical systems.

Accomplishments

Southern Research designed, installed and commissioned a skid that was fully integrated with a slip stream from NCCC's. The skid was designed to receive up to 5 lb/h raw syngas augmented with bottled syngas to adjust the H2/CO molar ratio to 2, clean it to cobalt FT catalyst specifications, and produce liquid FT products at the design capacity of 2 to 4 L/day. It employed a 2-inch diameter boiling water jacketed fixed-bed heat-exchange FT reactor incorporating Chevron’s catalyst in Intramicron’s high thermal conductivity micro-fibrous entrapped catalyst (MFEC) packing to efficiently remove heat produced by the highly exothermic FT reaction. A test was run for over 320+ hours including 70+ hours with Powder River basin (PRB) coal-derived syngas and 70 + hours with 80% PRB coal and 20% biomass-derived syngas. Ground hardwood pellets were used as the biomass fuel. Smooth operation with a seamless switch between various sources of syngas/fuel was achieved successfully demonstrating the design production rate of >> 2 L/day with about 75% carbon selectivity to liquids. Efficient heat removal and hydrocarbon productivities more than 4 fold higher than conventional catalysts were demonstrated. The liquid product produced was nearly wax-free. The minor catalyst deactivation that was observed over the duration of the test was linked to traces of sulfur in the gas accumulating on the catalyst. Comparative analyses of products from the CTL test with 100% PRB coal and CBTL test with 80% PRB coal and 20% ground wood pellets did not show differences between the productivity, selectivity, and distribution of liquid products. Preliminary technical and economic analysis (TEA) indicated that there was significant capital cost and product cost reduction due to the use of a high activity/selectivity catalyst and elimination of wax upgrading, but competition with petroleum-based liquids would require collective improvements/cost reductions in other major CTL/CBTL plant operations as well. Addition of biomass to coal reduced the carbon foot print of CBTL compared to CTL and brought it closer to the carbon foot print of petroleum-based fuel production processes.