Contract No. R003-009
"Fischer-Tropsch Fuels Development"

Submitted by Energy & Environmental Research Center
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PARTICIPANTS

Sponsor	Cost Share
Energy & Environmental Research Center Utilizing U.S. Department of Energy National Energy Technology Laboratory funding	$710,786
North Dakota Industrial Commission	$189,034*
Total Project Cost	$899,820

Project Schedule – 12 months
Contract Date – October 22, 2008
Start Date – October 1, 2008
Completion Date – March 31, 2010

Project Deliverables:
Status Report: December 31, 2008 √
Status Report: March 31, 2009 √
Status Report – June 30, 2009 √
Status Report – September 30, 2009 √
Status Report – December 31, 2009 √
Final Report– March 31, 2010 √

*The final costs for this project came in under budget. The Commission's funding was reduced by $6,420.75. This amount is not reflected in the amount approved for funding.

OBJECTIVE/STATEMENT OF WORK:
To prepare pilot-scale testing equipment and perform testing in the areas of Fischer-Tropsch (FT) liquid production, catalyst development, catalyst testing, product upgrade, and process simulation. Biomass-derived syngases will be used for the testing. The FT pilot system will be combined with existing Energy & Environmental Research Center gasifiers to provide the capabilities to allow testing of current and newly developed catalysts with syngas from various fuels and at conditions of varied temperature, pressure, and gas composition. The catalyst development and production work will supply catalyst options for varied end use applications, including use in smaller-scale, distributed fuel production systems. The development of FT technologies to produce liquid transportation fuels from biomass, waste and coal will provide a new industry for North Dakota as well as helping to provide energy security not only for the state but for the entire country.

STATUS
Contract executed

First status report received April 7, 2009. During first quarter learned that the catalyst produced by project partners at Brigham Young University will be delayed until summer of 2009. An alternative FT catalyst developed and tested at EERD will be used for initial system shakedown. Equipment construction is complete and instrumentation is nearly completed. Preparation for the shakedown testing is nearly complete.

Second status report received April 7, 2009. During the January 1 – March 31, 2009 quarter the Fischer-Tropsch reactor system and gasifier construction was completed. A process simulation model was also completed. The process simulation model is now being used to predict the effect of various processing scenarios, such as recycle streams and intermediate separation steps. The model results will assist in formulating test plans for catalyst testing in the coming months. System shakedown has been delayed into the next quarter.

A request has been made and approved for a no-cost extension for the final report from September 30 to December 31, 2009.

Third status report received the first week of August, 2009. During the April 1 – June 30, 2009 quarter the EERC completed shakedown of all the reactor components in the Fischer-Tropsch (FT) reactor and fluid-bed gasifier. A large batch of iron-based catalyst was loaded into the FT reactor in preparation for initial testing. EERC has analyzed and prepared a large batch of torrefied biomass for cogasification with coal and FY synthesis. The torrefaction process converts the biomass into a hard friable product similar to pulverized coal, increasing the heating value and carbon content while decreasing the moisture. Catalyst manufacturing equipment has been procured and will be used to produce a large batch of FT catalyst using a formulation provided by Calvin Bartholomew at Brigham Young University.

The project status report for the period of July 1 – September 30, 2009 was received the first week of November, 2009. During this time period the EERC completed two gasification and Fischer-Tropsch (FT) tests, generating several liters of hydrocarbon product. The first week of testing involved the gasification of a subbituminous Powder River Basin (PRB) coal and several blends of 70% PRB coal with 30% biomass. Biomass samples were blended raw, leached, and torrefied. During the second week of testing, PRB coal was again gasified, but 100% biomass was fed to the gasifier for several hours at the end of testing. Mass balance across the gasifier during the first week shows 72% carbon conversion, and mass balance across the FT reactor showed 70% conversion of carbon monoxide and hydrogen into FT products.

A request has been made and approved for a no-cost extension for the final report from December 31, 2009 to March 31, 2010. An additional status report is to be submitted on December 31, 2009.

The project status report for the period of October 1, 2009 – December 31, 2009 was received in mid-January, 2010. During this time period the EERC completed two gasification and Fischer-Tropsch (FT) tests: one during the week of October 5 and one during the week of November 30. This brings the total number of weeklong bench-scale FT tests completed under this project to four. Feed composition during the tests conducted in this quarter varied between 100% coal and 100% biomass. The coal used for all tests conducted during this quarter was North Dakota lignite. Three different biomass materials including switchgrass, dried distiller's grains and soluble (DDGS), and olive pits were used in gasification/cogasification tests with lignite to product FT liquids. DDGS and switchgrass were taken from North Dakota, while olive pits were received from Greece. Samples of FT liquids were hydrotreated and upgraded to a product that nearly met military specifications for jet fuel (JP-8). The product was not fully upgraded because the mass loss from an additional pass through the hydrotreater and distillation column would have been prohibitive given the small sample size (less than 100g). Results from testing were presented at a large international coal conference and a paper has been submitted to a well-known industry journal. These reporting efforts will attract interest in the viability of North Dakota coal and biomass energy resources and should also help to bring further research funding into the state of North Dakota through the EERC.

The final report has been received and is posted on the Industrial Commission/Renewable Energy Program website. The final report notes the following:

For this Energy & Environmental Research Center project, a high-pressure fluidized-bed gasifier (FBG) was coupled to a bench-scale packed-bed Fischer-Tropsch (FT) reactor. Two coal types were gasified: a North Dakota lignite and a Powder River Basin subbituminous, both of which are used in North Dakota. In addition, three biomass types were cogasified with the coal also gasified straight: switchgrass and dried distiller's grains and soluble (DDGS) from North Dakota sources and olive pits from Greece. The olive pits were gasified because they had been pretreated as part of the project that generated the switchgrass and DDGS, and it was thought that testing this available feedstock would generate comparative data that might illustrate the relative advantages or drawbacks of the two North Dakota biomass feeds.

Syngas was cleaned by using hot sorbent beds to remove H_2S and water-cooled quench pots to remove waters and tars. The gasifier was successfully operated on all coal and biomass types. Biomass pretreatment by leaching helped to prevent ash agglomeration when cofeeding 30% biomass with coal (either subbituminous or lignite), and biomass torrefaction led to higher gasification temperatures. Untreated biomass led to agglomeration, demonstrating that leaching had helped to improve the gasification potential of the biomass. Issues with gasifier operation prevented any clear results as to whether long-term, sustainable gasification of 100% biomass (that is, without coal blending) was feasible on this system.

Heating various fittings and valves was necessary when ambient temperatures dropped, as the colder temperatures led to plugging of exposed lines by condensed tars. This solution may not be feasible for sustained, long-term operation of small-scale distributed gasification and FT technologies. For a smaller gasifier with minimal auxiliary systems to be operated continuously for a long duration, the system design will need to either avoid tar production or ensure adequate tar and water removal.

The packed-bed FT reactor achieved sustained liquid synthesis and temperature control, demonstrating the feasibility of this design for small-scale operation. However, catalyst deactivation was apparent both from reactor operation and product analysis. The primary cause of deactivation appears to have been oxidation due to high CO_2 concentrations. Gasification tars may also have contributed to catalyst deactivation by coking. An attempt was made to regenerate the catalyst, with no noticeable impact on catalyst activity, suggesting more than one mode of catalyst deactivation.

A process for generating kilogram-scale quantities of pelletized iron-based catalyst was conceived of, constructed, and tested. Although the process was successful, the catalyst generated by this process was produced too late to be used for testing in the packed-bed FT reactor.

Using AspenPlus™ software, a computer-based model was developed that is capable of accurately predicting the gas composition from the gasifier. Early results from laboratory-scale FT synthesis were used to generate equations for predicting the behavior of the packed-bed FT reactor. However, the syngas composition from the gasifier was sufficiently different from the composition used in the laboratory-scale reactor that the model could not accurately predict the distribution of various components in the FT liquids. (The model may be useful to the North Dakota Industrial Commission in future FT projects, and it will be useful for attracting gasification and FT research dollars to the EERC and by extension to the State of North Dakota.)

The liquid product from the packed-bed FT reactor was upgraded to improve its fuel qualities. Although not required by the proposal, the aim of the upgrading effort was to generate specification-compliant jet fuel. The product quality was much improved by hydrotreating, but product enhancement did not fully convert the FT product into jet fuel. The effort demonstrated the feasibility of a FT product-upgrading process and also identified key issues to be considered if the goal of upgrading FT liquids is to produce jet fuel.

Updated 5/27/10