Baard Energy, L.L.C. - Idaho National Laboratory

Plant Modeling
&
Emissions Comparative Analysis Approach
Coal/Biomass Gasification with Fischer-Tropsch Diesel Production

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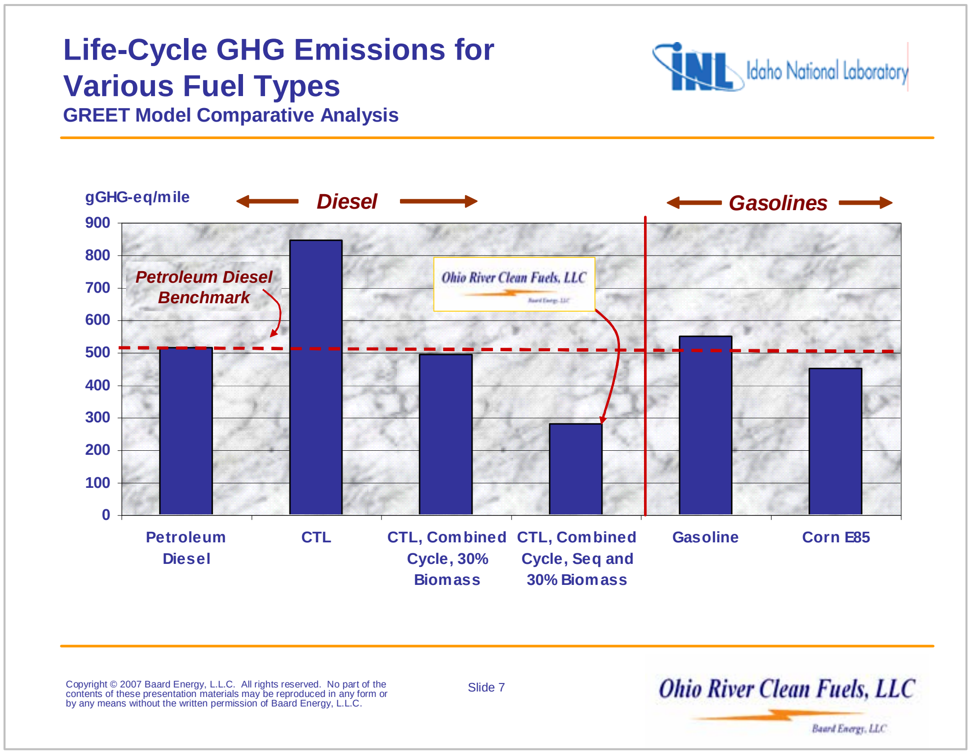
Introduction

Baard Energy, L.L.C., through its project company Ohio River Clean Fuels, L.L.C., has announced that it is building a 50,000 barrel per day coal to liquids (CTL) plant in Wellsville, Ohio. The plant will employ Fischer-Tropsch (FT) technology to convert synthesis gas produced by the gasification of coal and biomass to ultra-clean FT diesel, FT jet, and FT naphtha synthetic hydrocarbons.

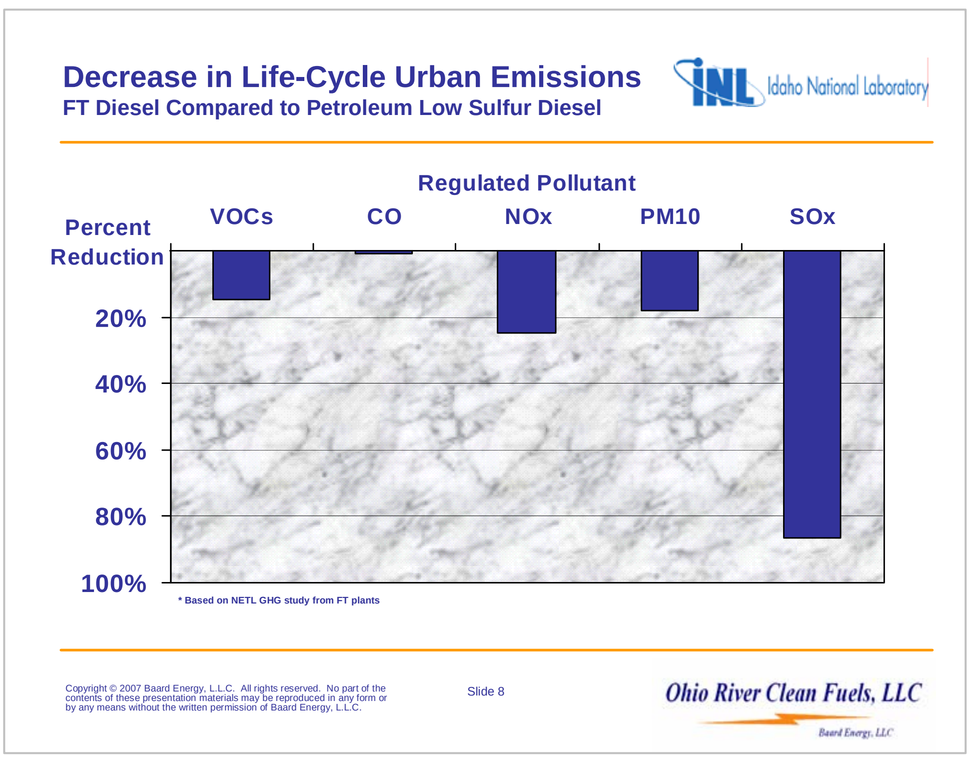
Due to trade secret protections, there is an absence of accurate engineering data concerning FT fuels. Because of this, Baard Energy entered into a Cooperative Research and Development Agreement (CRADA) with the Idaho National Laboratory (INL) to use previously developed process engineering information of the Ohio River Clean Fuels plant and other well-recognized analyses of alternative fuels to establish a credible comparison of the Baard fuels and other transportation fuels: petroleum diesel, gasoline and blends of gasoline and ethanol. According to the year-long INL study of the Ohio River Clean Fuels project-modeling, Baard Energy's FT fuels will emit 46 percent less emissions of carbon dioxide and other greenhouse gases than conventional diesel transportation fuels. All emission reductions documented in the study were measured on a Well-to-Wheels basis using the Argonne National Lab GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model of transportation fuels.

The INL study demonstrates that with proper design and technology selection, FT fuels can also dramatically reduce emissions of regulated pollutants when compared to low-sulfur diesel fuel. Baard's virtually sulfur-free FT fuel will reduce emissions of sulfur dioxide by 86 percent and cut nitrogen oxide emissions by 25 percent. In addition, INL found that Baard's FT fuel will reduce particulate matter emissions by 18 percent, emissions of volatile organic compounds by 15 percent, and also reduce emissions of carbon monoxide by one percent. Please see the accompanying charts on the following page showing Life-Cycle Greenhouse Gas Emissions and criteria pollutants for fuels produced by the Ohio River Clean Fuels, L.L.C. plant compared to petroleum diesel, gasoline, and blends of gasoline and ethanol.

A full technical report is scheduled to be delivered by Baard Energy and the Idaho National Laboratory at the 24th Annual International Pittsburgh Coal Conference in Johannesburg, South Africa, September 10-14, 2007.



The chart to the left shows the GHG emissions per mile traveled for various fuels. The first bar is ultra-low sulfur petroleum diesel. The second bar is a CTL plant without carbon controls. The third bar shows the Ohio River Clean Fuels plant with process improvements and 30% biomass additions. This plant is approximately 4% better than petroleum diesel. The fourth bar is the Ohio River Clean Fuels plant with carbon capture and sequestration of 85% of the produced carbon; a 46% reduction in GHG emissions. This design case has been approved by the Board of Directors to be built. The last two bars show gasoline and E85.



The chart to the left shows the reduction in criteria pollutants that can be achieved when substituting Baard's FT diesel for petroleum grade ultra-low sulfur petroleum diesel.

Baard Energy Coal/Biomass to Liquids Plant Design Model

INL entered into a CRADA with Baard Energy, L.L.C. to develop a process simulation model for a Fischer-Tropsch plant based on coal and biomass feedstock gasification, syngas cleaning/conditioning, fuels synthesis and refining, and power generation operations specified by Baard Energy. The proprietary model developed by INL and Baard Energy has been reviewed and was used by private engineering groups contracted by Baard Energy to support conceptual design options and front end engineering design studies (FEED). With the completion of the Phase I FEED study, the model enables Baard Energy to quickly estimate material and energy balances for the plant and to quantify emissions sources and rates for carbon dioxide (CO_2) and criteria pollutants.

Indirect Coal Liquefaction Principles

The Baard Energy Fischer-Tropsch plant uses gasification to convert coal and blends of coal and biomass to carbon monoxide (CO) and hydrogen (H_2), the primary reactants which are then converted over a selective catalyst to FT diesel, FT jet, and FT naphtha. This is considered an indirect conversion process that was developed and pioneered by German scientists Franz Fischer and Hans Tropsch early in the last century. While thousands of patents pertaining to indirect coal and biomass liquefaction have been issued, only a few plants have been built around the world due to plant complexity and costs relative to crude oil and other fuels production.

Recently, there have been claims that FT plants and the use of FT fuels results in significantly higher pollutant emissions, especially green house gases such as CO_2. Carbon dioxide is generated when CO is shifted with steam to create adequate H_2 for the FT reactors, as shown in the following reaction: $CO + H_2O \leftrightarrow CO_2 + H_2$. Additionally, CO_2 is produced when the light tail-gases (synthetic natural gas) from the FT reactor are combusted in a natural gas combustion turbine to generate electricity to operate the plant. Concerns for CO_2 emissions provide incentive to design an optimally efficient FT synthetic fuels plant that separates and captures the CO_2 so it can be used for enhanced oil recovery, algae production, or sequestered in a suitable geological formation. The Baard FT plant design was tailored to reduce greenhouse gas emissions by implementing biomass as a feedstock and by selecting various process configurations and unit operations that allow the CO_2 to be minimized, concentrated, and captured at optimal locations in the process.

FT Diesel Emissions - Comparative Analysis Approach

A comparative emissions analysis of the Baard Energy FT fuels plant was completed by the INL. This effort involved reviewing other DOE liquefaction studies and authoritative literature and calculating Well-to-Wheels emissions for the Baard FT plant in a manner that is consistent with established practices and metrics.

A Well-to-Wheels analysis accounts for all of the energy and associated emissions resulting from production of the resource. In the case of petroleum diesel and gasoline, the analysis includes emissions and energy for crude recovery, transportation of the crude from the well to the refinery, energy and emissions at the refining processes, transportation, distribution of the refined petroleum fuels to the pump, and tailpipe emissions during vehicle operations.

In the case of corn ethanol, the model analyzes the feedstock inputs such as natural gas for fertilizers, fuels, and associated emissions generated during planting, harvesting, and transportation of corn to the ethanol production plants, emissions and energy used at the ethanol plant, transportation of ethanol to the ethanol-gasoline blending facilities, and transportation/distribution of ethanol blends to the fuel pumps. All emissions from the use of these ethanol/gasoline blends are also tabulated.

In the case of coal and biomass, the model analyzes fuels and emissions beginning at the mine or gathering of the biomass (wood-waste), transportation of the coal and biomass feedstocks to the FT facility, emissions and energy used at the FT facility and transportation and distribution of the FT fuels to the pump. Again, the process also analyzes the anticipated tailpipe emissions during use of the FT fuels. The analysis of advanced fuel/vehicle systems energy use, greenhouse gas emissions, and criteria pollutants by General Motors (GM) and Argonne National Laboratory (ANL) provided a comprehensive and convenient reference for the Baard Energy study.[1] The life cycle greenhouse gas emissions inventory for FT fuels plants completed by the U.S. DOE National Energy Technology Laboratory (DOE-NETL)[2] and Princeton University[3] were also used for the emissions comparison study.

The Baard plant included integration of best available process technology and configuration to achieve an optimal carbon-management strategy. Proper carbon management was the overall objective of the Baard engineers. The plant is designed to capture and sell or sequester approximately 80% of the carbon input at the Ohio River Clean Fuels plant. Future sequestration techniques are currently being considered which could lead to another 15% carbon capture in the early life of the project.

The major drivers for realizing optimal carbon management were:

- Selection of gasification technology which allows for maximum input of biomass feedstock. Use of significant fractions of biomass allows for a significant renewable component for synthesis gas production at the gasifiers.
- Configuration of the various process units of the plant which also have a direct impact on efficiency with respect to CO_2 production and capture. Baard performed a number of unit configuration studies which led to minimal CO_2 production (reducing process inefficiencies) as well as creation of a concentrated stream of clean CO_2 (95% purity) for the most cost-effective extraction.
- Other process parameters which allow for minimization of wasted process streams in order to optimize FT production, which minimizes process CO_2 production.

In summary, the Well-to-Wheels emissions calculations for the Baard Energy coal-biomass FT fuels plant include the emissions associated with the energy required to grow and/or produce, transport, and prepare the biomass feedstock, and also the energy to recover and ship the coal to the plant. Energy consumption and emissions rates for the FT plant were obtained from the integrated plant model developed by the INL and the Baard Energy design engineers. These first two steps are comparable to the Well-to-Tank portion of a Well-to-Wheels analysis. The Tank-to-Wheel portion of the INL calculations used inputs and assumptions consistent with the GM/ANL GREET model (Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation). In this manner, CO_2 emissions were calculated for the life-cycle of the

[1] Norman Brinkman (GM), Michael Wang (ANL), Trudy Weber (GM), and Thomas Darlington (Air Improvements Resource, Inc), “Well-to-Wheel Analysis of Advanced Fuel/Vehicle Systems – A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions,” May, 2005.
[2] John Marano and Jared Ciferno, “Life-Cycle Greenhouse-Gas Emissions Inventory for Fischer-Tropsch Fuels,” June, 2001.
[3] Robert H. Williams, Eric D. Larson, and Haiming Jin, “Synthetic Fuels in a world with High Oil and Carbon Prices,” 8th International Conference on Greenhouse Gas Control Technologies, Trondheim, Norway, 19-22 June, 2006.

carbon extracted and converted to energy and fuel, plus the CO_2 emissions resulting from final combustion of the fuel in a diesel engine.

The comparative study on urban emissions of criteria pollutants was limited to the Tank-to-Wheels emissions associated with vehicles using a representative FT diesel versus a low-sulfur crude diesel in an urban area. Reduction in sulfur pollutant emissions reflects the ultra-low levels of sulfur in FT diesel. Emissions reduction in nitrogen oxides (NO_x), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM) reflect improved engine performance on synthetic fuels. Further, FT diesel contains no nitrogen in the fuel. This reduces NO_x levels emitted from an engine burning FT fuels. In the future, when FT fuels are substituted in power mining machinery, trucks, and locomotives used for feedstock transportation, the FT fuels will further reduce total life-cycle greenhouse gas emissions and criteria pollutants from the mine-mouth to wheel.

INL Modular Process Simulator Development

The Baard Energy modular process model developed by INL uses HYSYS™, Aspen Plus™ and other Aspen simulation tools with user function and auxiliary code implementation capability to more accurately model kinetic and transport governed processes. These models are being used to study process integration and optimization, and to develop supervisory controls and virtual test beds for complex integrated gasification, FT fuels, and chemical synthesis processes. The models are calibrated using data from published DOE gasification project reports and vendor-supplied data for appurtenant unit operations. In this manner, a high level of confidence is achieved for overall plant modeling case studies.

Several universities are supporting the INL model development activities, including the University of Wyoming, Brigham Young University, Pennsylvania State University, and Rensselaer Polytechnic Institute. Partners also include Battelle Memorial Institute, other national laboratories, and private industry. Private industry is engaged through the DOE Work for Others (WFO) program and CRADAs. Participation by industry is performed at the request of such entities, subject to approval by DOE.

Working with Baard Energy, the INL process modeling group worked to integrate process models and systematically investigated plant design and cost-benefit tradeoff options. The modular code allows alternative technology, stream recycle, heat recovery concepts, and variable operating conditions to the parameters to be explored. Such studies lead to process insights and help minimize plant emissions and water use and other process efficiency improvements.

About Baard Energy, L.L.C.

Baard Energy is a privately held limited liability company that develops finances, constructs, and owns alternative fuel projects including ethanol, biodiesel, coal to liquids and biomass to liquids facilities. Based in Vancouver, Washington, Baard Energy has over twenty years experience in alternative energy and fuels. Over the past 20 years, Baard and its affiliates have developed a variety of energy projects, including wood-waste and natural gas electric generating facilities and ethanol production plants used for transportation fuels. Since 1998, and in response to an increased demand for alternative fuel sources, Baard has been working on the engineering and design of coal to liquids (CTL) and biomass to liquids (BTL) technologies.

About Idaho National Laboratory

The Idaho National Laboratory (INL) was formed in 2005 by the U.S. Department of Energy by combining research personnel and resources from the former Idaho National Engineering and Environmental Laboratory (INEEL) and Argonne National Laboratory - West (ANL-W). Located in Southeastern Idaho near western energy reserves, the INL has three main research facilities; 1) Reactor Technology Complex, 2) Materials and Fuels Complex, and 3) Science and Technology Campus. The INL was established to be the preeminent nuclear energy laboratory with synergistic missions in national homeland security, and multi-programs in secure, clean, and efficient energy using nuclear, renewable, and fossil energy resources. The INL is managed by Battelle Energy Alliance (BEA), a team consisting of management from Battelle Memorial Institute (BMI), Electric Power & Research Institute (EPRI), Babcock & Wilcox Technologies (BWXT), Washington Group International (WGI), and Massachusetts Institute of Technology (MIT).

Through the DOE Laboratory Directed Research and Development (LDRD) program, INL is advancing process modeling and simulation capabilities and conducting fundamental scientific studies in several key energy-related areas, including CO_2 management, biomass feedstock assembly and preparation, gasification, syngas cleaning, catalysis, and high temperature electrolysis. One activity focuses on development of a modular process model for simulating complex poly-generation plants, such as a fully-integrated Fischer-Tropsch synthetic fuels plant.