Statement of Project Objectives

Ohio River Clean Fuels

CO_2 Production & Emissions Study (OH)

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Objectives

This project will increase technical understanding and public confidence in building an industry in the U.S. for converting the nation's abundant supply of coal with biomass to synthetic fuels in order to reduce U.S. reliance on expensive and diminishing domestic and foreign crude reserves. The principal objective of this work will be the development of uniform method to account for life cycle greenhouse gas (GHG) emissions associated with the production of synthetic fuels, chemicals, and electrical power using coal and biomass feedstocks (referred to as coal and biomass-to-liquids, or CBLT). This objective shall be accomplished by the following activities:

1) Organizing and facilitating a collaborative workshop with leading academic authorities, governmental energy and environmental agencies, and commercial project developers to develop a unified set of assumptions and methods to calculate GHG emissions for CBTL plants in the U.S.;

2) Development of a reference table for GHG emissions associated with fuels and chemical products produced by from U.S. domestic and leading foreign sources of petroleum crude.

3) Development of a model base to calculate GHG emissions as a function of CBLT plant design, operating conditions, and product selection;

4) Completing a parametric study of GHG emissions for a representative CBLT plant as a function of feedstock selection, product output variation, and CO_2 management options;

5) Providing one or more technical publications and one or more public presentations based on peer-reviewed results of the study workshop and modeling results

Background

Baard Energy Congressionally-Directed Projects

The primary mission of the U.S. Department of Energy Fossil Energy Program (DOE-FE) is to help support the development of clean, affordable energy using the nation's vast resources of oil, coal, natural gas, and oil shale. Both domestic and international energy consumption will of necessity increase if continued economic

growth is to be achieved. It is imperative that replacement fuels be developed to offset the decline in conventional U.S. oil production along with unsecure non-domestic sources. DOE-FE is therefore supporting priority projects such as clean coal plants, more productive oil and gas fields, and the continuing readiness of federal emergency oil stockpiles. Because CO_2 emissions are attributed to atmospheric climate warming, DOE-FE is also funding CO_2 sequestration projects aimed at reducing GHG emissions. The goal is to conduct large-scale demonstration projects to verify the technical and economic viability of CO_2 capture, pipeline transport to a suitable sequestration location, and safe, permanent disposition in the subsurface.

Section 526 of the 2007 Energy Policy Act directs the U.S. government, including the U.S. Military, to only purchase fuels that have life cycle carbon emissions equivalent or better than fuels made from conventional crude oil. Concurrently, the United States Air Force has the goal of replacing 50% of its fuel consumption with such clean fuels by 2016. Other branches of the Defense has also set fuel replacement goals. This provides additional incentive for DOE-FE to develop clean substitution fuels.
Baard Energy, LLC, has been awarded three Congressionally-directed projects that will help DOE-FE achieve its primary mission and clean coal conversion goals while also demonstrating it is possible to exceed the standards established by EPAct 2007. The trilogy of correlated projects include:

1) A practical study of technology, energy requirements, and economics to capture, compress, transport in a pipeline, and inject a high purity CO_2 stream produced by the Ohio River Clean Fuels (ORCF) coal/biomass-to-liquids synthetic fuels plant project in Ohio to a carbon capture site in close proximity to the plant. The amount of CO_2 that is co-produced as a consequence of the chemical energy and hydrogen production that are required to gasify the coal and biomass and to produce the proper ratio of clean CO and H_2 necessary for liquid fuels production is significant. (Wood et al., ORCF Project Process Model and Greenhouse Gas Emissions Calculations).

2) A practical demonstration of permanent CO_2 disposition at a geological site which in this case will be a depleted oil reservoir. This activity will commence with a single-well "Huff-n-Puff" test using approximately 80 tons of CO_2.

3) Accurate assessment of the life-cycle GHG emissions associated with the production and consumption of replacement fuels and other products produced by the CBTL plant. This activity will be coordinated with, and will also support the U.S. EPA Office of Transportation/Air Quality, NETL, and other organizations directed by EPA or Congress to establish a consistent and accurate procedure for determining GHG emissions associated with alternative fuels production.

These projects will collectively determine the environmental benefits and the costs of blending biomass feedstock with coal to produce synthetic fuels while using the by-product CO_2 for enhanced oil recovery (EOR) to produce additional crude oil. If a CO_2 flood for EOR is properly designed, a significant fraction of the CO_2 will remain permanently sequestered. This project will provide limited technical data to validate this opportunity.

The basis for these studies will be the Baard Energy Ohio River Clean Fuels Project that is planned for construction in Wellsville Ohio, with projected operations commencing in 2012. Technology to convert coal and biomass to transportation fuels (known as CBTL for coal-and-biomass-to-liquids) is considered technically viable and commercially available. Current market conditions provide clear economic signals supporting capital investment for the production of gasoline, diesel, and jet fuels, with possible co-generation of electrical power and other by-products from domestic sources of coal and biomass. Baard Energy has therefore taken the initiative to design a plant that can capture, purify, and use or sequester the CO_2 produced by a CBTL plant. This set of studies will close an important technology gap necessary to prove CBTL with EOR can achieve the cleanliness standard sought by DOE-FE.

Ohio River Clean Fuels (ORCF)

ORCF, a coal/biomass-to-liquids facility to be built at Wellsville, Ohio, will have a production capacity of 52,500 bpd comprised of three identical trains running in parallel.

Each train will have two gasifiers feeding into one Fischer-Tropsch (FT) reactor producing 17,500 bpd of FT fuels, including diesel, jet fuel and naphtha. In order to manage such a large and complex construction process, the construction of the three trains will be staggered by 12 months. The first train will take 36 months to complete. Accordingly, the commercial operation date for the second train will follow the completion of the first train by approximately 12 months, followed by the third train after another 12 months. The refining process will be constructed with the first train and will have sufficient capacity to handle the output from all three trains. The project will utilize the Rectisol™ process to clean, isolate and capture CO_2 for use in Enhanced Oil Recovery (EOR) or sequestration.

Greenhouse Gas Emissions

Greenhouse gases (GHGs) are defined as those gases which trap solar and radiant terrestrial energy leading to atmospheric warming. Among the several gases emitted by human activities and natural processes, three significant GHGs are notably on the rise- N_2O, CH_4, and CO_2. Production and combustion of fossil fuels is considered a leading contributor to anthropogenic GHG emissions, primarily due to emissions of CO_2. Vehicle transportation fuels contribute to approximately one-third of the total emissions for fossil fuels.

Except for a small percentage of biofuels such as ethanol and bio-diesel, most transportation fuels used in the U.S. are produced from petroleum crude that is supplied by both domestic and foreign oil wells. All crude oil is refined using heat provided from combustion of a fraction of the oil to produce fuel distillates, including gasoline, diesel, and jet fuels. Heavy crude requires more energy to refine and thus produces higher levels of GHG emissions. In the case of ground transportation vehicles, the life cycle of GHG emissions per mile driven is summed for the emissions associated with crude oil extraction and deliver of the crude to the refinery, refining the various petroleum distillates, the deliver of the refined fuels to the pump, and the final combustion of the refined fuels. This is referred to as a "well-to-wheel" (WTW) GHG emissions assessment. In the case of a jet engine or a maritime vessel, it could be referred to as a "well-to-wake" life cycle emissions assessment. In the WTW evaluation for biofuels, GHG emissions also include emissions from tilling the soil, applying fertilizers which are produced primarily from

natural gas, harvesting the crops, and converting the bio-material to fuels. However, crops that are re-planted are considered "renewable" and remove CO_2 from the atmosphere. There are numerous aspects of carbon disposition that must be included in a life-cycle GHG emissions assessment for each fuel type. It is little wonder then that many GHG emissions studies have been completed, often with different results.

GHG Emissions Assessment Needs Statement

An accurate and unified method is needed to quantify and qualify the life-cycle disposition of carbon, water, and natural resources used as feedstocks to produce replacement fuels and chemicals for petroleum crude and its derivates. Section 526 of the Energy Security and Independence Act of 2007 (P.L. 110-140) is highly problematic since neither a standard method for calculating GHG emissions, nor a consistent approach for source attribution from a systems perspective has been presently established. For example, differing sources of crude oil will exhibit a wide range of WTW emission profiles. The heavier Venezuelan crudes or heavy crudes derived from the Canadian Oil Sands have higher WTW profiles than fuels produced from lighter or sweet crudes. This project will aid academic leaders and governmental agencies in the development of an informed and accurate method for calculating GHG life cycle emissions for a representative CBTL plant.

Predictive tools which can efficiently calculate GHG emissions as a function of feedstock choices, technology choices, and product options. An accurate and credible method for determining and qualifying operating conditions that will meet [likely] future GHG emissions standards, and the expectations of our society, is needed. This tool will thus support the creation of new energy and acceptable replacement fuels for continued economic growth of our nation.

Scope of Project

This project will encompass the following activities:

- Organize and facilitate a workshop to develop a unified set of assumptions and methods to calculate GHG emissions for CBTL plants in the U.S. Participants in this workshop

shall include leading academic authorities and national laboratories currently making GHG emissions projections, federal transportation and environmental agencies charged with completing or understanding GHG emissions assessments, and commercial CBTL project developers. A DOE-authored, participant-reviewed report on the workshop discussions and outcomes will be issued to the participating entities and interested organizations, such as the Interagency Working Group on Alternative Fuels, the United Mining Association, the Gasification Technologies Council, U.S. DOE, U.S. EPA, and others.

- Review and refine GHG WTW emissions for U.S. domestic crude and the top foreign suppliers, e.g. Arabia, Canada, Venezuela, (or others) to establish a recognized standard for CBLT plant fuels and chemical products comparison. Following this review, a reference table for GHG emissions associated with fuels and chemical products produced by from U.S. domestic and leading foreign sources of petroleum crude will be assembled.

- Develop a user-friendly spreadsheet model based on the unified assumptions and methods to calculate GHG emissions as a function of CBLT plant design, operating, and product variables. A user interface will be developed for inputting manual data and for automatically receiving and translating data from the Baard Energy synthetic fuels process models developed previously (and revised simultaneously by the project) for a CBLT plant. This spreadsheet model will automatically tabulate and graph GHG emissions for the user-specified feedstock options, plant operating conditions, and plant products.

- Complete a parametric study of GHG emissions as a function of feedstock selection, product output variation, and CO_2 management options. The Ohio River Clean Fuels (ORCF) Plant will be used as the basis for this investigation.

- Produce one or more peer-reviewed technical publication and make one or more public presentations based on the results of this study. A DOE public release report covering the entire project will be produced by the Idaho National Laboratory, with co-authorship by NETL and ANL, as their interests may apply.

A technical paper will be submitted to a scholarly scientific journal. Public presentations shall be made at national and internationally recognized conferences, such as the Gasification Technologies Council Annual Meeting and Symposium.

Tasks and Subtasks to be performed

Task 1 CBTL GHG Emissions Calculation Workshop

Several greenhouse gas emissions studies have been completed over the past 10 years. The GREET (*Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation*) model developed by Argonne National Laboratory is a comprehensive, highly regarded Excel spreadsheet program that uses input information to calculate WTW emissions for a range of crude-based and biomass based synthetic fuels and advanced vehicle fleet options (Wang et. al., 2008). NETL has focused primarily on fossil fuel WTW and equivalent analysis, most recently publishing a study on CBLT (Reed, et al., 2007). NREL began focusing on biomass and coal gasification power system GHG emissions in the 1990's (Spath, et al., 1999). Emissions studies have also been previously completed by INL (Baard, et al., 2007), Princeton University (Williams, 2007), University of California – Davis (Delucchi, 2002), and others. Each of these studies invoke specific assumptions, use different levels of tools (i.e., spreadsheets, process models, equilibrium codes) and provide calculations for specific reference plants. The different studies provide generally similar, but differing results depending on plant design, byproducts, and plant optimization.

Baard Energy has proposed to develop a unified set of assumptions and calculation methods to project life-cycle GHG emissions for CBTL plants. These methods may require proprietary technology design information that may only be available to project developers. The use of validated engineering data, supported by ASPEN Plus modeling, is proposed to be the appropriate manner for establishing a "gold standard" for GHG emissions calculations for legislative purposes and individual project qualification. It is

therefore imperative that organizations and individuals publishing GHG emissions data come to agreement on the approach that will provide the most accurate and most reliable method for custom plant assessments.

Baard Energy has already received commitments from several individuals making GHG emissions calculations, as well as the EPA and other Federal and State leads, to participate in a workshop that would help create a uniform standard. These agencies include the U.S. Department of Defense Strategic Fuels leads, the U.S. EPA Air Quality/Transportation Board, and the Air Transportation Association. Baard Energy will organize and facilitate the workshop, following with a team-reviewed publication summarizing the workshop findings and recommendations. The following tasks and subtasks shall be completed:

Subtask 1.1 Review recent GHG reports and models

Subtask 1.1.1 Identify and collect most current reports from Princeton, MIT, NETL, ALN, INL, Air Transport Association, private project developers, others.

Subtask 1.1.2 Develop a table of comparative model assumptions, CBLT design features, and calculation approaches

The table will include assumptions ranging from resource production to product use and byproduct disposition, including assumptions and calculations that assess conventional crude and crude-derived products, biomass production and supply, CBTL conversion process options and differences. This will help to understand and determine the basis for differences among currently published results.

Subtask 1.1.3 Determine Federal agency GHG data needs and priorities

The project principals will contact the U.S. EPA (Division of Air Quality and Transportation), Federal Aviation Administration, Aviation Transportation Association of America, American Public Transportation Association, and Department of Defense logistical fuels, etc. to determine synthetic fuels use and permitting requirements.

Subtask 1.1.4 Summarize GHG similarities, differences and contradictions in report

This document will serve as a primer for understanding and addressing potential data gaps and data needs for making accurate GHG life-cycle calculations for conventional and CBTL fuels and chemicals production.

Subtask 1.2 Organize and Facilitate GHG WTW Technical Workshop

This workshop will likely be held in the Washington DC area to conveniently accommodate leading technical and federal agencies. The minimum target participants include DOE-NETL (Dr. John Weimer and/or designees), DOE-ANL (Dr. Wang), DOE-INL (Dr. Richard Boardman and/or designees), U.S. Environmental Protection agencies, PA, Federal Aviation Administration (FAA) leads, Air Transportation Association (ATA), academic authorities (Princeton, MIT, U.C Davis, Harvard, and Stanford, as their interests and availability may apply). Workshop participation by commercial CBLT project developers will also be requested. Participation by commercial entities will be voluntary whereas funding for travel and limit labor will be provided to government and academic participants when necessary.

Subtask 1.2.1 Review CBTL GHG Life-Cycle Emissions Model Assumptions and Data Needs

The purpose of this exercise is to critically evaluate model assumptions invoked by the current studies and to identify data gaps.

Subtask 1.2.2 Develop consistent set of requirements for qualifying and permitting synthetic fuels

This purpose of this exercise will be to establish a fair basis to evaluate synthetic fuels, including not only GHG emissions, but other criteria and listed pollutants. Other key environmental impacts and benefits will be concurrently addressed.

Subtask 1.2.3 Evaluate and critique separate GHG models

The purpose of this subtask is to arrive at consensus on methods for apportioning GHG emissions to conventional crude and CBLT products; for example, in accordance with and energy or mass allocation among products and by-products. This exercise will attempt to ensure emissions sources and credits are considered and summed in a consistent and uniform manner.

Subtask 1.3 Issue Workshop Report to Participants, DOE, and Federal Agencies

The purpose of this report is to provide a guidance document to federal agencies and organizations developing policy and regulations for the governance of transportation fuels. This document will also serve as a technical needs document to support the role of federal research programs.

Subtask 1.3.1 Develop workshop report

The draft report will be completed by the INL under subcontract of Baard Energy

Subtask 1.3.2 Review workshop report

Key workshop participants will be asked to review the workshop report for content completeness and accuracy.

Subtask 1.3.3 Issue workshop report to participants and agencies.

Task 2 Establish Standard WTW Emissions for Representative Crude-Derived Fuels

The purpose of this task is to provide a technical review and possible revision of WTW emissions for conventional crude produced in the U.S. and leading foreign suppliers. This standard is needed as a reference for CBTL fuels and chemicals. The task will be accomplished in part during Task 1. Additional calculations will be completed as determined necessary and sufficient by the working group and in consultation with petroleum refiners and others. Results from this task will be included in the Workshop accomplishments report.

Task 2.1 Review & Revise Previous WTW GHG Emissions for Crude-Derived Fuels

Task 2.2 Develop a Spreadsheet to Calculate WTW GHG Emissions

Based on key assumptions that vary depending on location, crude API gravity, composition, and other factors.

Task 3 Develop Life-Cycle GHG Emissions Model for CBTL Plant

The purpose of this task is to provide Baard Energy with a computational tool to assess plant operating and production GHG emissions assessments. This model will incorporate the uniform assumptions and calculation methods prescribed by the workshop. A user interface will be developed for inputting manual data and for automatically receiving and translating data from a detailed process Aspen model for a CBLT plant (specifically the ORCF Project). This spreadsheet model will automatically tabulate and graph GHG emissions for the user-specified feedstock options, plant operating conditions, and plant products.

The Idaho National Laboratory will complete this task.

Task 3.1 Refine CBTL Aspen Model Modules

The INL and Baard Energy, under a work for others agreement with Baard Energy, have previously developed an Aspen model to complete mass and energy balances for equipment design and integration. This model will be expanded to include various technology options under the subtasks that follow:

Task 3.1.1 Aspen Module for Biomass Preparation and Supply

Biomass is contains moisture and has specific queue, drying, grinding/milling specification. INL will develop Aspen routines to represent M&E balances and equipment sizing associated with these unit operations.

Task 3.1.2 Aspen Module for Biomass Gasification

Biomass gasification can be accomplished by two methods: Co-injecting the biomass into a large-scale commercial gasifier; or, operating a dedicated biomass gasifier. The Idaho National Laboratory will develop routines to accomplish the second of these methods. Both a fixed-bed and a fluid-bed gasifier are candidates for separate biomass gasification.

Task 3.1.3 Aspen Module for Iron-Based Fischer-Tropsch

The INL will adapt an existing Fe-FT Aspen module for the ORCF project. New arrangements of gas cleaning and CO_2 removal will be completed under this activity.

Task 3.1.4 Aspen Module for Methanol Synthesis

Methanol is a building is a building block for synthetic fuels, specifically di-methyl ether and higher oxygenates that are fungible with petroleum gasoline derivatives.

Task 3.1.5 Aspen Module for Methanol to Gasoline

An Aspen block for the ExxonMobile process for producing high oxygenates from methanol may be developed using proprietary data provided under a nondisclosure agreement with ExxonMobile, if possible.

Task 3.1.6 Aspen Module for Air-Air Cooling Tower

In order to conserve water use, air-air coolers can be used to condense low-grade steam to recycle in a CBTL plant. Modules will be added to the Baard CBLT plant to investigate the benefits and impacts of this technology on GHG emissions.

Task 3.1.7 Aspen integration with Data Base Program

This task will include data transfer between a custom data base, such as Excel, Access, or a similar data management program.

Task 3.2 Develop GHG Database Interface Model

The purpose of this task is to provide an efficient tool to project GHG emissions as a function of user-specified plant operating conditions. A data base which simplifies user input for modeling various CBLT cases will be developed with adequate prompts and

instructions to enable project principals to determine GHG emissions associated with key CBLT variable. The interface model will use macros and sub-programs to calculate, tabulate, and plot air emissions and other key plant operating conditions.

Subtask 3.2.1 Develop spreadsheet program to specify user inputs

An interface to enable efficient input of plant operating conditions and output specifications will be provided. This will include feedstock definitions, plant operating conditions, product specifications, and other pertinent variables. Macros will be used to translate input data into common units and quantities used to calculate the emissions for the specified case.

Subtask 3.2.2 Develop Data Base of Pre-Computed Aspen Cases

In order to provide a GHG tool for efficient use, a series of pre-computed Aspen Cases will be completed to generate a look-up table of operating conditions and outputs that can be readily accessed via an interpolation scheme for unique user-specified cases.

Subtask 3.2.3 Develop algorithm to calculate GHG emissions

GHG emissions will be calculated using spreadsheet functions, macros, and embedded FORTRAN models that access the Aspen pre-computed solutions or which command new Aspen simulations. This program will automatically tabulate the results and generate printable graphics for case studies.

Subtask 3.2.4 Document Example Cases

An interim project report will be provided to DOE documenting the approach and outcomes of Task 3..

Task 4. Complete Parametric Studies for CBTL GHG Emissions

The purpose of this task is to complete a parametric investigation of plant feedstock selection, plant operating conditions, and product specifications to understand the range of operating conditions and revenue potential of CBTL. The following cases, for example may be investigated in a multi-dimensional matrix.

- 0, 10, 20, 30, 40, 50% biomass co-feed
- 0, 30, 50, 75% carbon capture and sequestration
- Co versus Fe FT Catalyst
- Methanol to DME and/or gasoline case, versus diesel and jet fuel

Task 5 Reporting

This activity will provide new understanding for operating CBLT plants. Reporting shall consist of three forms;

- DOE Project Level Report
- Scientific Publications
- Technical Conference Presentations

Task 5.1 DOE Project Level Report

At the conclusion of the parametric study, a overall report documenting the workshop decisions and GHG emissions modeling study will be completed. This report will not contain proprietary project information, but shall document the methods used to outcomes for the ORCF project plant GHG emissions as a function of operating conditions. The Idaho National Laboratory will complete this report with review from Baard Energy principals. DOE-NETL will be asked to review a draft report prior to publication.

Task 5.2 Scientific Publication

It is anticipated that the parametric studies will provide information for at least one peer-reviewed article that will be submitted to an appropriate technical journal. A comparison of GHG emissions and plant revenues potential as a function of feedstock choices and product decisions may be summarized in this article.

Task 5.3 Technical Conference Presentation

The results of this work will be prepared and presented at one or more technical conferences addressing clean coal, synthetic fuels, and GHG emissions. Appropriate briefings to DOE, EPA, DOD, FAA, and ATA will also be given by Baard Energy.

Project Management

Project Management Plan.

A Project Management Plan (PMP) will be developed and submitted for DOE approval 30 days from project award. The PMP will include an overview of the project, a risk management plan (if required), project organization and structure, work breakdown structure, project schedule, project milestones, project deliverables, budget summary and cost plan, and success criteria and decision points. Guidance on format will be provided by the DOE.

Quarterly Status Reports.

Status of progress and activities performed during each quarter will be summarized in a Quarterly Report and submitted to DOE no later than 30 days following the reporting period. Guidance on format will be provided by the DOE.

Final Report.

A comprehensive final report will be submitted to DOE no later than 60 days following the completion of work.

Financial Audit

If required an audit of the project will be performed.