EERC
Energy & Environmental Research Center®
Putting Research into Practice

University of North Dakota
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www.undeerc.org

May 1, 2015

Ms. Karlene Fine
Executive Director
ATTN: Renewable Energy Development Program
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2015-0199 Entitled "Biomass to Refinery Feedstock-Grade Liquids"

The Energy & Environmental Research Center (EERC) of the University of North Dakota is pleased to submit an original and one copy of the subject proposal. Also enclosed is the $100 application fee. The EERC is committed to completing the project as described in the proposal if the Commission makes the requested grant. A letter of cost share, commitment, and support can be found in Appendix A.

If you have any questions, please contact me by telephone at (701) 777-5243 or by e-mail at bfolkedahl@undeerc.org.

Sincerely,

Bruce C. Folkedahl
Research Manager

Approved by:

Thomas A. Erickson, Director
Energy & Environmental Research Center

BCF/kal

Enclosures

Renewable Energy Program

North Dakota Industrial Commission

Application

Project Title: Biomass to Refinery Feedstock-Grade Liquids

Applicant: Energy & Environmental Research Center, University of North Dakota

Principal Investigator: Bruce C. Folkedahl

Date of Application: May 1, 2015

Amount of Request: $304,543

Total Amount of Proposed Project: $609,086

Duration of Project: 12 months

Point of Contact (POC): Bruce C. Folkedahl

POC Telephone: (701) 777-5243

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POC Address: 15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

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ABSTRACT

Objective: Optimize a gasification–Fischer–Tropsch-based biomass-to-liquids (BTL) technology and develop a preliminary engineering design for a demonstration-scale BTL system capable of converting manure and other low-value biomass resources to hydrocarbon mixtures suitable for direct use as petroleum refinery feedstocks.

Expected Results: A set of commercially viable BTL process operating conditions and a "Front-End Engineering Level 2" (FEL-2) design package (including preliminary equipment selection and design, process flow diagram, fabrication schedule, and ±30% cost estimate) for a 25-barrel/day BTL plant.

Duration: 12 months

Total Project Cost: Total project cost is $609,086, of which $304,543 is being requested from the North Dakota Renewable Energy Council as match to $304,543 from commercial partners.

Participants: EERC, Epcot Crenshaw Corporation, and American Refining Group.

PROJECT DESCRIPTION

Objectives

The overall goal of the proposed project is to optimize biomass-to-liquids (BTL) systems and methods for converting animal manure and other biomass resources to fuel- and/or lubricant-grade hydrocarbons suitable as petroleum refinery feedstocks. The ability to cost-effectively convert waste to hydrocarbon refinery inputs at a distributed scale is an emerging need of the agriculture, food-processing, and municipal waste-processing industries. When properly executed, gasification of biomass wastes (and other feedstocks) and steam-reforming of bio-derived methane-rich gases (from anaerobic digesters, landfills, and other sources) can yield a clean and combustible mixture of CO, H_2, CH_4, CO_2, and N_2 known as a "syngas." Efficiently produced syngas carries a major fraction of the chemical energy contained in the material used to produce it. Syngas can be fed to a catalytic Fischer–Tropsch (FT) process to yield refinery feedstocks for production of fuels and high-value lubricants and specialty chemicals. In addition to valuable liquid products, gasification processes can also yield an ash coproduct with value as a soil amendment.

In the proposed project, the Energy & Environmental Research Center (EERC) will work with Epcot Crenshaw Corporation (ECC) and American Refinery Group (ARG)—a distributed renewable energy systems developer and a petroleum refinery operator with significant lubricant and specialty chemicals production capabilities, respectively—in optimization of gasification- and reforming-based FT technology pathways for converting renewables to high-value refinery feedstocks. Key objectives include:

1. Operation and optimization of the EERC advanced fixed-bed gasifier (AFBG) to generate data and information for use in assessing key factors related to sustainable gasification of manure and agriculture residues to yield a clean syngas suitable for introduction into an FT reactor system.
2. Operation of the EERC bench-scale FT reactor system to assess the performance of ECC-specified FT catalyst(s) in conversion of "bottled" syngas to a hydrocarbon mixture suitable as a refinery feedstock for lubricant and specialty chemicals production. To be ideally suited for this purpose,

the hydrocarbon mixture will have a "carbon number distribution" that ranges from about C_{14} to C_{22}, with major concentration at about C_{18}.

3. Operation of a reactor system comprising the EERC entrained-flow reactor (EFR) integrated with the EERC pilot-scale FT reactor, to enable optimization of a process comprising methane conversion (via "steam methane reforming" [SMR]) to a syngas that is converted (via FT reaction) to a C_{18}-rich refinery feedstock.
4. Development of a preliminary design for a 25-barrel/day (b/d) integrated gasification–FT plant capable of converting manure and other biomass resources into high-value refinery feedstocks. The design will leverage key findings of the process optimization efforts and will serve as the basis for fabrication of a 25-b/d BTL process demonstration unit.

Methodology

The proposed project comprises the following five tasks:

- Task 1 – Characterize manure and other selected biomass feedstocks based on energy, moisture, total ash, sulfur, and metals contents.
- Task 2 – Utilize the EERC bench-scale FT system to evaluate the performance of one or more ECC-specified FT catalyst(s) with 1) a nitrogen-rich syngas and 2) a nitrogen-deficient syngas, representing the output of an air-blown and an oxygen-blown gasifier, respectively.
- Task 3 – Quantify the behavior of manure and other selected biomass feedstock(s) in the AFBG gasifier, and optimize the gasification system and process to enable reliable feedstock conversion to a syngas sufficiently clean to safely be introduced into an FT reactor system.
- Task 4 – Operate the integrated EFR–FT system to convert methane and carbon dioxide (in ratios representative of an anaerobic digester or landfill gas) to a C_{18}-rich hydrocarbon refinery feedstock.
- Task 5 – Utilize project-acquired data and fundamental computational process modeling to develop a preliminary (Front-End Loading – Level 2 [FEL-2]) design and cost estimate for a skid-mounted demonstration-scale (25-b/d) integrated gasifier–FT reactor system.

Anticipated Results

Anticipated results include 1) detailed characterization of selected biomass feedstocks, 2) optimization of the AFBG system and process and use of the optimized system/process to demonstrate production of a clean syngas and a carbonaceous soil amendment, 3) use of the EFR–FT system to demonstrate production of a lubricant/specialty chemicals-grade refinery feedstock, and 3) development of an FEL-2 design and cost estimate for a skid-mounted demonstration-scale (25-b/d) integrated gasifier–FT reactor system for deployment as the next step in process commercialization.

Facilities

EERC laboratory, pilot plant, and office space comprises over 250,000 square feet dedicated to energy and environmental research, development, demonstration, and commercialization. The EERC maintains a wide range of laboratories and equipment for chemical process development and analysis and characterization of solid, liquid, and gaseous reactants and products. These highly sophisticated and diverse tools are transportable between research programs. Specific equipment to be used in this proposed project includes the EERC lab scale FT reactor system, AFBG system (shown in Figure 1), and pilot-scale EFR–FT reactor system. The EERC lab-scale FT reactor system is used to perform small-scale, long-term (unattended operation) evaluation of FT catalyst performance. More information on the AFBG system is provided in subsequent sections of this proposal. The pilot-scale FT reactor system is capable of liquid production at a rate of up to 4 liters (1 gallon) per day per catalyst bed. The FT reactor system meters up to 100 “standard liters per minute” (3.5 “stand cubic feet per minute” per catalyst bed of clean, pressure-regulated syngas through a preheater and then into a set of down-flow, parallel-packed shell-and-tube reactors. The reactor beds can operate at up to 70 bar (1000 psig) and 300°C (570°F), and the system has been utilized to test both EERC-developed and commercial FT catalysts.

Resources

The EERC is a research facility that operates as a business unit of the University of North Dakota. The EERC has a multidisciplinary staff of 220 scientists, engineers, and technicians with expertise in a broad

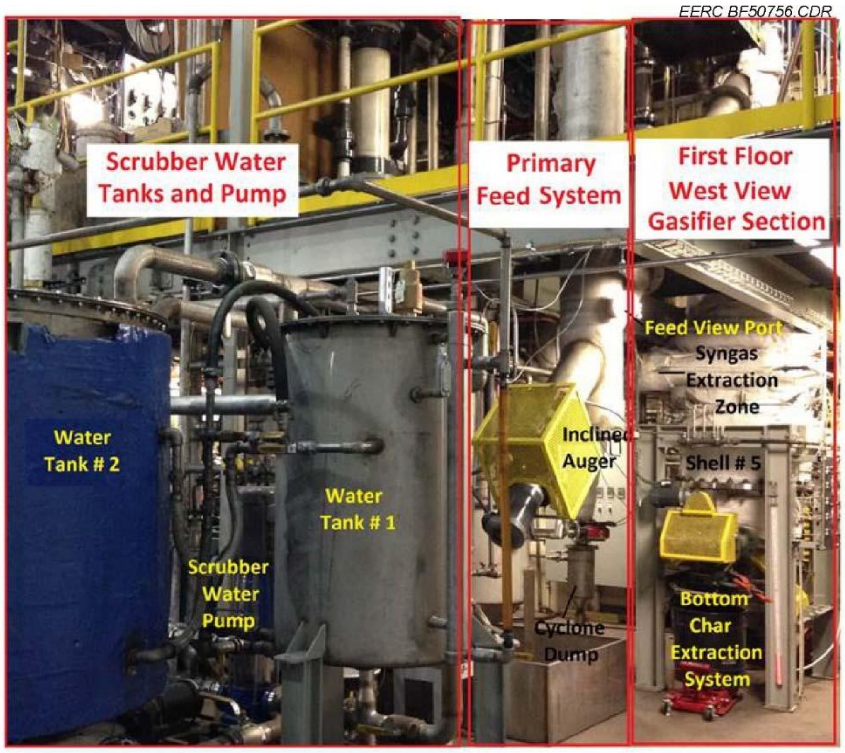

Figure 1. AFBG system installed in EERC Gasification Process Development Facility.

spectrum of energy and environmental programs, including over 60 years of research experience in gasification process development, biomass characterization, and renewable fuels and chemicals production via FT and other processes. All of the equipment and expertise necessary for the proposed project are available to the project team for use on the project as needed.

Techniques to Be Used, Their Availability, and Capability

Task 1 – Feedstock Characterization – Selected feedstocks will be characterized based on proximate analysis, ultimate analysis, and ash compositional (including metals) analysis.

Task 2 – Bench-Scale FT Testing – FT catalyst performance evaluation tests will be conducted using the EERC bench-scale FT reactor, which was designed and built by the EERC about 8 years ago and which has been used to evaluate many different FT catalysts and FT operating conditions. An ECC-specified catalyst will be evaluated with two different syngas compositions—the first being nitrogen-rich, representing a syngas produced in an air-blown gasifier, and the second being nitrogen-depleted,

representing a syngas produced in an oxygen-blown gasifier. Run time for each syngas composition will be at least 5 days to allow attainment of steady-state operation and generation of sufficient product for analysis. Products will be collected in condenser pots at the outlet of the FT reactor system and analyzed for quality and quantity.

Task 3 – Pilot-Scale Gasification Testing – Testing will be performed with the AFBG, which is rated at a nominal feed rate of 40 to 60 pounds per hour. The EERC recommends conducting a minimum 8-hour shakedown test for the selected feedstock to initially assess its behavior and determine if any specific gasifier optimization is required to ensure optimal performance. Upon satisfactory completion of shakedown, the AFBG will be operated for a nominal 4-day (up to 100-hour) period. At the end of this initial test period, the data from the test will be summarized and reviewed by the EERC, any needed system and/or operational parameter adjustments will be made, and a second longer-duration test of approximately 10 days will be initiated. The purpose of this test program is to assess gasifier operation at a relatively fixed set of operating conditions for an extended period of time. This is required to identify any accumulative, time-dependent issues that may not have been identified during earlier short-duration optimization testing. If desired or required during the test, one (or more) selected process parameters may be varied to assess impact on performance; however, a key objective of this activity is to attain and maintain steady-state operation.

Previous EERC gasification work with manure feedstocks indicates that ash clinkering may be a problem because of the high potassium levels typically associated with livestock waste. If generated, ash clinkers will be analyzed to understand and address the ash agglomeration mechanism at the temperature profile experienced by the agglomerate. Thermal profiles along the length of the reactor will be monitored and recorded. The product gas stream generated will be measured for flow rate and gas composition (contents of CO_2, CO, H_2, O_2, N_2, H_2S, CH_4, C_2H_6, C_2H_4, and H_2O). Provisions will be made to collect all residual materials after solids removal and prior to gas-phase composition analysis. The solids (biochar and ash) materials will be collected to correlate with each set of process variables evaluated.

Task 4 – Methane Reforming and FT Liquid Production – The EFR will be integrated with the EERC syngas cleanup and pilot-scale FT units, and the integrated system will be operated to produce a C_{18}-rich hydrocarbon mixture. The FT reactor will use catalyst material specified and/or supplied by ECC. The pilot-scale EFR will be modified to enable its use in SMR mode; this modification will include piping and compressor additions. The test period for this activity will be 4 to 5 days of continuous operation of the integrated system. The FT liquids will be collected on a daily sampling schedule and analyzed for composition. Additionally, unconverted gas will be analyzed on a continuous basis by an online Raman spectra laser gas analyzer with the capability of measuring CO, CO_2, H_2, CH_4, N_2, O_2 and higher-hydrocarbon concentrations. Conversion efficiencies will be calculated for the FT test runs. Periodic samples of the unconverted gas will be obtained and analyzed using a state-of-the-art refinery gas analyzer to provide a more detailed look at the gas composition.

Task 5 – FEL-2 Integrated Gasifier–FT Reactor System Design – Project-acquired data and fundamental computational process modeling will be used to develop an initial design and cost estimate for a skid-mounted demonstration-scale (25-b/d) integrated gasifier–FT reactor system. FEL-2 design requirements include preliminary equipment selection and design, and development of a preliminary process flow diagram, fabrication schedule, and ±30% cost estimate.

Environmental and Economic Impacts While Project Is under Way

Since this is a laboratory- and pilot-scale project that will be conducted within the EERC, no adverse environmental or economic impacts are anticipated.

Ultimate Technological and Economic Impacts

The proposed distributed-scale BTL process eliminates the cost of transporting low-energy-density biomass resources to centralized processing locations. Gasification–FT-based production of renewable hydrocarbons from currently unused or underused biomass resources offers the potential of introducing renewables into a petroleum refinery. Leveraging existing refinery capacity to process renewable intermediates into saleable products makes economic sense, because standalone, completely vertically

integrated biomass refineries are prohibitively expensive to build and operate. It is a long-sought goal of the U.S. Department of Energy (DOE) office of Energy Efficiency and Renewable Energy to develop a commercially competitive technology for converting a biomass-derived hydrocarbon of sufficient quality to enable its direct feeding into refinery without costly pretreatments. If successful, the proposed project will result in a technology that achieves this DOE goal, and also provides opportunities for expanded utilization of North Dakota biomass resources.

Why the Project Is Needed

While North Dakota is rich in fossil fuels, including coal and oil and gas, the state is also abundant in renewable biomass resources such as animal manures, crop residues, municipal tree trimmings, and biomass waste and has the potential for energy crop production. Creating new markets for biomass in the state has the benefit of producing new jobs and economic development opportunities. As witnessed lately, fluctuations in crop pricing can make North Dakota's traditional family farming legacy difficult to sustain. One way to bring added stability to the farming industry is to provide new markets for products that are already being produced and are unused (such as animal manures), as well as adding new energy crops to the rotation. The ability to produce commercially competitive renewable hydrocarbon liquids that meet petroleum refinery feedstock specifications will generate these new market opportunities.

STANDARDS OF SUCCESS

Listed below are the measurable deliverables for the project. Project success will culminate in a design for a demonstration system that will be implemented in a follow-on project. This demonstration phase will prove out the technology, providing the basis for full-scale commercial deployment of the technology.

Deliverables

Deliverables will include 1) quarterly progress reports; 2) a BTL demonstration system preliminary (FEL-2) design; 3) presentation of results to project sponsors; and 4) a final project report, including an economic viability assessment and a funding strategy for deployment of a BTL demonstration system.

Value to North Dakota

ECC and ARG have been pursuing development of a gasification–FT-based BTL process for 8 years. Their objective is to commercialize a process that is sufficiently robust and reliable to convert manure and other difficult-to-process (because of high moisture and ash contents) biomass wastes to hydrocarbon mixtures of sufficient quality to enable their direct use (without pretreatment) as petroleum refinery feedstocks. As a refinery operator, ARG understands the logistical and economic risks associated with augmenting petroleum feedstocks with biomass-derived feedstocks and is uniquely qualified to establish a "BTL refinery feedstock chemical and physical property specification," compliance with which will ensure the commercial viability of a biomass-derived hydrocarbon mixture and the BTL process that produced it. By working with ECC and ARG on the proposed BTL technology development effort, the EERC is assured that the proposed effort is properly focused on a meaningful commercial target and that, if successful, the results will have commercial relevance.

The primary challenge associated with a gasification–FT-based BTL process is a gasifier that works. This means that the gasifier needs to operate sustainably and economically and consistently yield a clean syngas of sufficient quality to enable its direct routing to an FT unit, which—to operate effectively—requires an input gas of consistent quality and free of even trace-level contaminants. ECC and ARG recognize this challenge and approached the EERC to join their team based on the EERC's experience in designing gasifiers that work. Manure is an especially problematic agricultural waste because of its potential for uncontrolled runoff into surface and groundwaters, and the EERC designed the AFBG specifically for processing and extracting value from manures and other high-moisture and high-ash-content feedstocks. The AFBG comprises two gasification reaction zones for enhanced control of the gasification process and complete waste destruction. The AFBG also has specially designed vertical augers to extract solid residue and avoid clinkering issues often associated with gasification of manures and other high-ash-content feedstocks. In order to achieve zero effluent discharge and improve syngas composition (quality), the effluent from the syngas scrubber is injected into the gasifier. Condensed tar and particulate matter, along with a small fraction of water, are injected into the reactor hot zone such that

the hydrodynamics of the reactor temperature profile are not affected. The AFBG can also be operated in a manner such that along with the inert ash, a fraction of carbon can be produced to be utilized as a soil amendment.

In the proposed project, ECC–ARG and the EERC will optimize the AFBG with the objective of commercializing it for application to manure and other high-moisture/ash feedstocks. The EERC is currently working with an EERC spin-off company, Grand Forks-based Singularity Energy Technologies (SET), to develop a business strategy for AFBG commercialization. A key component of the strategy is a plan for AFBG system manufacture in North Dakota. Assuming project success, SET will be well-positioned to develop this manufacturing capability. Although at least 2 to 3 years out, an AFBG manufacturing plant would translate to 30 to 60 high-quality jobs and would position North Dakota to capitalize on upcoming opportunities in biomass gasification, a business sector with a lot of promise that is—as of yet—untapped.

BACKGROUND/QUALIFICATIONS

Project Team

The proposed EERC project team has developed the proof-of-concept study, built the reactor systems to perform the experimental work, performed previous gasification and FT experimental work and analyzed the results, and produced reports and papers to document process development progress. Commercial partners ECC and ARG will provide process and product commercialization guidance to ensure EERC process development efforts are properly focused on real and meaningful commercial targets.

Prior Experience

In addition to performing several gasification and FT bench- and pilot-scale studies, the project team—in cooperation with EERC colleagues—has designed and built several laboratory–pilot-scale reactor systems for process development, including bench- and pilot-scale FT fixed-bed reactor systems for testing (commercial and EERC-developed) FT catalysts (1), a pilot-scale direct liquefaction system capable of

generating about 2 gallons/day of jet fuel distillation-range raw liquids, and a system to convert up to 4 liters/hour of triacylglyceride feedstock to jet fuel.

MANAGEMENT

The EERC has a long history of successfully managing projects with multiple partners both large and small. The EERC has partnered and worked with many biofuel producers, including Archer Daniels Midland, Blue Flint Energy, ICM, Lanzatech, and Chippewa Valley Ethanol Company. The EERC has also partnered with other international organizations, including Siemens, GE, and 3M, and has been awarded many DOE, U.S. Environmental Protection Agency, U.S. Department of Agriculture, Defense Advanced Research Projects Agency, and ARPA-E (Advanced Research Projects Agency– Energy) competitive contracts.

Dr. Bruce Folkedahl will be the project manager for this proposed project. Dr. Folkedahl has managed many large projects such as the EERC Center for Biomass Utilization®, a multiyear, $10,000,000 DOE project with 15 commercial sponsors, a $1,400,000 project for development of a novel water capture technology for power production with Siemens Power and DOE as partners, and numerous other projects in his 15-plus years of experience at the EERC.

Evaluation points during the project will occur at Milestone 2 and Milestone 4 as depicted in Table 1. At these points, the project team will make the decision to proceed or to halt the project based on the success of the project at that juncture. For Milestone 2, the project will proceed if the catalyst selected has the desired hydrocarbon chain length selectivity. For Milestone 4, the project will proceed if the pilot-scale testing has provided sufficient evidence to support the development of a demonstration-scale design.

TIMETABLE

Table 1. Project Milestones

Milestone	Description	Achieved By (Month)
1	Kickoff meeting with project sponsors	1
2	Laboratory-scale process optimization study	5
3	Pilot-scale process demonstration	8
4	Economic and engineering assessment	9
5	Demonstration system FEL-2-level design	10
6	Project results presentation to sponsors	11
7	Final report to sponsors	12

BUDGET

A budget justification for the associated budget can be found in Appendix B.

CATEGORY	Epcot Crenshaw Share	NDIC Renewable Energy Program Share	Project Total
Total Labor	$ 211,727	$ 229,039	$ 440,766
Travel	$ -	$ 5,326	$ 5,326
Equipment > $5000	$ 7,000	$ -	$ 7,000
Supplies	$ 24,261	$ 23,082	$ 47,343
Other*	$ 720	$ 347	$ 1,067
Laboratory Fees & Services			
Natural Materials Analytical Research Lab	$ 4,752	$ 11,176	$ 15,928
Fuels & Materials Research Lab	$ 5,125	$ 6,026	$ 11,151
Particulate Analysis Lab	$ 5,813	$ 10,934	$ 16,747
Process Chemistry & Development Lab	$ 5,931	$ 11,157	$ 17,088
GC/MS Lab	$ 9,984	$ -	$ 9,984
Fuel Preparation Service	$ 1,757	$ 2,754	$ 4,511
Continuous Fluidized-Bed Reactor Service	$ 21,166	$ -	$ 21,166
Graphics Service	$ 1,248	$ 1,174	$ 2,422
Shop & Operations	$ 5,059	$ 3,528	$ 8,587
Total Project Cost – U.S. Dollars	$ 304,543	$ 304,543	$ 609,086

*May include costs such as food, printing, communications, or other miscellaneous expenses.

TAX LIABILITY

The EERC, a department within the University of North Dakota, is a state-controlled institution of higher education and is not a taxable entity; therefore, it has no tax liability.

CONFIDENTIAL INFORMATION

There is no confidential information in this proposal.

PATENTS/RIGHTS TO TECHNICAL DATA

The EERC has pending patent applications on the AFBG system and process based on previous work under separate contract. Any AFBG-related project-generated patentable material will remain the property of the EERC and the EERC Foundation®.

REFERENCE

1. Folkedahl, B.C.; Snyder, A.C.; Strege, J.R.; Bjorgaard, S.J. Process Development and Demonstration of Coal and Biomass Indirect Liquefaction to Synthetic Iso-Paraffinic Kerosene. *Fuel Process. Technol.* **2011,** *92*, 1939–1945.

APPENDIX A

LETTER OF COMMITMENT

EPCOT | CRENSHAW
Alternative Thinking • Alternative Approach

April 30, 2015

Ms. Karlene Fine
Executive Director
ATTN: Renewable Energy Development Program
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2015-0199, "Biomass to Refinery Feedstock - Grade Liquids"

This letter confirms Epcot Crenshaw Corporation (ECC) and American Refining Group (ARG) commitment of $304,543 in cash as cost share to the subject proposed project. ECC and ARG are also committed to developing, commercializing, and deploying high-efficiency technologies for conversion of biomass wastes to petroleum refinery feedstock, and view our partnership with EERC on the proposed project as critical to helping us achieve these objectives. We are interested in facility deployments where available biomass feedstock, affordable electricity and natural gas, and access to a petroleum refinery combine to yield a workable economic equation, and look forward to continued work with EERC to evaluate opportunities in North Dakota.

Should you have further questions please feel free to contact us using the information below.

Yours faithfully,

C. Satish Smith, MS, *TEC*-MBA
Chairman & Chief Executive Officer

www.epcotcrenshaw.com
Epcot Crenshaw Corporation
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Phone: 610.696.1635 • Fax: 800.481.0480

APPENDIX B

BUDGET JUSTIFICATION

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

BUDGET INFORMATION

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) and among funding sources of the same scope of work is for planning purposes only. The project manager may incur and allocate allowable project costs among the funding sources for this scope of work in accordance with Office of Management and Budget (OMB) Circular A-21.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the university's current fiscal year (July 1 – June 30). Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: Salary estimates are based on the scope of work and prior experience on projects of similar scope. Salary costs incurred are based on direct hourly effort on the project. As noted in the UND EERC Cost Accounting Standards Board Disclosure Statement, administrative salary and support costs which can be specifically identified to the project are direct-charged and not charged as facilities and

administrative (F&A) costs. Costs for general support services such as contracts and IP, accounting, human resources, procurement, and clerical support of these functions are charged as F&A costs.

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits. Only the actual approved rate will be charged to the project. The second component is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

Travel: Travel may include site visits, fieldwork, meetings, and conferences. Travel costs are estimated and paid in accordance with OMB Circular A-21, Section 53, and UND travel policies, which can be found at http://und.edu/finance-operations (Policies & Procedures, A–Z Policy Index, Travel). Daily meal rates are based on U.S. General Services Administration (GSA) rates unless further limited by UND travel policies; other estimates such as airfare, lodging, etc., are based on historical costs. Miscellaneous travel costs may include taxis, parking fees, Internet charges, long-distance phone, copies, faxes, shipping, and postage.

Equipment: A booster compressor will be purchased for the project. The compressor will be used to pressurize the syngas for introduction into the FT reactor.

Supplies: Supplies include items and materials that are necessary for the research project and can be directly identified to the project. Supply and material estimates are based on prior experience with similar projects. Examples of supply items are chemicals, gases, glassware, nuts, bolts, piping, data storage, paper, memory, software, toner cartridges, maps, sample containers, minor equipment (value less than $5000), signage, safety items, subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the F&A cost.

Communications: Telephone, cell phone, and fax line charges are included in the F&A cost; however, direct project costs may include line charges at remote locations, long-distance telephone

charges, postage, and other data or document transportation costs that can be directly identified to a project. Estimated costs are based on prior experience with similar projects.

Printing and Duplicating: Page rates are established annually by the university's duplicating center. Printing and duplicating costs are allocated to the appropriate funding source. Estimated costs are based on prior experience with similar projects.

Food: Expenditures for project partner meetings where the primary purpose is dissemination of technical information may include the cost of food. The project will not be charged for any costs exceeding the applicable GSA meal rate. EERC employees in attendance will not receive per diem reimbursement for meals that are paid by project funds. The estimated cost is based on the number and location of project partner meetings.

Operating Fees: Operating fees generally include EERC recharge centers, outside laboratories, and freight.

EERC recharge center rates are established annually.

Laboratory and analytical recharge fees are charged on a per-sample, hourly, or daily rate. Additionally, laboratory analyses may be performed outside the university when necessary. The estimated cost is based on the test protocol required for the scope of work.

Graphics recharge fees are based on an hourly rate for production of such items as report figures, posters, and/or images for presentations, maps, schematics, Web site design, brochures, and photographs. The estimated cost is based on prior experience with similar projects.

Shop and Operation recharge fees cover expenses of a designated group of individuals whose roles require specialized safety training and personal safety items. These individuals perform project activities in a pilot plant facility, remote location or laboratory and are also responsible for preserving a safe working environment in those areas. The rate includes such things as training for use of fall protection harnesses and respirators, CPR certification, annual physicals, protective clothing/eyewear, hazardous waste disposal fees, and labor for personnel to direct group activities. The estimated cost is based on the number of hours budgeted for this group of individuals.

Freight expenditures generally occur for outgoing items and field sample shipments.

Facilities and Administrative Cost: The F&A rate proposed herein is approved by the U.S. Department of Health and Human Services and is applied to modified total direct costs (MTDC). MTDC is defined as total direct costs less individual capital expenditures, such as equipment or software costing $5000 or more with a useful life of greater than 1 year, as well as subawards in excess of the first $25,000 for each award.

Required Funding: If funding less than what is requested is allocated, the project scope will need to be revised to reflect the lower funding level.

SINGULARITY ENERGY TECHNOLOGIES, LLC

3318 Royal Circle, Grand Forks, North Dakota- 58201
Phone: (701) 739 8720, EMAIL: singularityenergy@gmail.com

April 30, 2015

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2015-0155 Entitled "Biomass to Refinery Feedstock-Grade Liquids"

Singularity Energy Technology, LLC (SET) is a Grand Forks company that I founded to commercialize the advanced fixed bed gasifier (AFBG). As a gasification process engineer at the Energy & Environmental Research Center (EERC), I conceptualized and directed development of the AFBG specifically for application to high moisture/ash-content feedstocks that are relatively inexpensive but often difficult to sustainably feed to and process in a gasifier.

With success in the subject proposed project, SET will work with EERC, ECC/ARG, and others to further develop and implement a business strategy that will culminate in a North Dakota-sited manufacturing facility specializing in commercial production of gasification systems.

SET is committed and looks forward to working with EERC, ECC/ARG, and the North Dakota Industrial Commission on the proposed project to further optimize and demonstrate the commercial viability of the AFBG technology platform.

Sincerely,

Nikhil Patel, PhD
Chief Executive Officer
Singularity Energy Technology, LLC

EPCOT | CRENSHAW
Alternative Thinking • Alternative Approach

Wednesday, May 20, 2015

Ms. Karlene Fine
Executive Director
Renewable Energy Development Program
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2015-0155 Entitled "Biomass to Refinery Feedstock-Grade Liquids"

As detailed in our letter sent on April 30th, Epcot Crenshaw Corporation (ECC) and American Refining Group (ARG) are committed to providing $304,543 (cash) to the subject proposed project, and to working with EERC to develop and deploy commercially viable biomass-to-refinery-feedstock technologies. The key to commercial viability is an economic and reliable gasification technology, and ECC/ARG is excited to be working with EERC and EERC spin-off company Singularity Energy Technology (SET) on optimization of the EERC-developed, SET-licensed advanced fixed-bed gasifier (AFBG). Based on our extensive evaluation of commercial and near-commercial gasification systems, the AFBG offers the most likely-to-succeed approach to addressing the technical challenges of gasifying high ash-content biomass feedstocks.

We understand that a key SET objective is to design, build, and start-up, in North Dakota, a production facility capable of manufacturing AFBG systems ranging in input capacity from tens to hundreds of tons/day, and we're committed to working with EERC and SET on optimizing and demonstrating the commercial viability of the AFBG technology, with the objective of being the first customer for a North Dakota-built gasifier.

On behalf of ECC/ARG, I reiterate our commitment to the proposed technology development program, and look forward to working with EERC, SET, and the North Dakota Industrial Commission on realizing the economic benefits (to both ECC/ARG and North Dakota) of a new high-tech manufacturing capability.

Yours faithfully,

C. Satish Smith, MS, *TEC*-MBA
Chairman & Chief Executive Officer

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