Environment and Natural Resources Trust Fund
2011-2012 Request for Proposals (RFP)

LCCMR ID: 166-F3+4

Project Title: Gasification of Cellulosic Biomass: Mitigation of Tar Formation

Category: F3+4. Renewable Energy

Total Project Budget: $ $421,021

Proposed Project Time Period for the Funding Requested: 3 yrs, July 2011 - June 2014

Other Non-State Funds: $ 256,606

Summary:

Project seeks to 1) develop a fundamental understanding of tar formation from biomass in high pressure gasifiers and 2) establish the benefits that torrefaction of biomass provides to gasifier performance.

Name: Duane Goetsch

Sponsoring Organization: SynGas Technology, LLC

Address: 11080 Industrial Cir NW

Elk River MN 55330

Telephone Number: 763-717-9490

Email dgoetsch@syngastechnology.com

Web Address www.syngastechnology.com

Location

Region: Statewide

Ecological Section: Statewide

County Name: Statewide

City / Township:

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ Employment	_____ TOTAL _____%

PROJECT TITLE: GASIFICATION OF CELLULOSIC BIOMASS: MITIGATION OF TAR FORMATION

I. PROJECT STATEMENT

Renewable specification fuels (ASTM D-4814 gasoline and D-975 diesel) can be produced from syngas made by gasification of cellulosic biomass. The key barrier to competitive production of these fuels is the cost of "cleaning up" the syngas to the requirements of the catalytic conversion processes that produce these fuels. The upgrading of the syngas involves: 1) acid gas removal [HCl, HCN, H_2S, etc.], 2) CO_2 removal, 3) tar and soot removal, and 4) compression. The first two areas depend directly on the composition of the biomass feedstock. The last two areas directly depend on the gasifier design.

Development of a high pressure gasifier for biomass has the potential to reduce operating costs by 20% and capital costs by as much as 100M$ per facility. Cost reductions of this magnitude create an opportunity to advance statewide renewable fuel production, confirm the state's leadership role in development of the technology, and supports job-growth in manufacturing, operations, maintenance, feedstock production and processing.

Large biomass particle sizes create poor mixing in the gasifier and results in localized temperature and concentration gradients that create conditions favorable to forming carbon or soot. Char is produced from the incomplete gasification of the lignin. Tars are made by the reaction between aldehydes produced from hemi-celluloses and phenol produced from lignin. Gasifier design and biomass feedstock processing has a significant effect on overall performance. Depending on gasification conditions, biomass can produce small amounts of soot, char, and tar when used to make syngas. Even small amounts of these materials result in a waste stream that is difficult and costly to handle. Torrefaction offers a potential pretreatment solution, in that hydrolysis removes the functional groups from hemi-cellulose that produce aldehydes in the gasifier. Reductions in the components that produce tar should directly reduce the amount of tar and the rate that tar is produced.

This project seeks to 1) develop a fundamental understanding of tar formation from biomass in high pressure gasifiers and 2) establish any benefits that torrefaction of biomass provides to gasifier performance.

The project will involve pilot plant studies to evaluate the effect of torrefaction severity on the compositional makeup of selected biomass. Torrefied biomass will then be used in a high pressure gasifier pilot plant to determine how gasifier performance is affected in terms of tar and char formation. This information will be used to estimate the economic benefits of torrefaction on gasifier performance.

II. DESCRIPTION OF PROJECT ACTIVITIES

The program requires the procurement of biomass followed by processing at representative torrefaction conditions. Biomass will be supplied by the agricultural cooperative Rural Advantage based in Madelia, Minnesota. SynGas Technology will process each biomass type in a small scale torrefaction facility. The torrefied biomass produced will then be used in gasification studies to access tar and char formation. The results of these studies will then be used to conduct a cost benefit analysis of the effect of torrefaction on gasification. All activities associated with securing, storing, and preparing torrefied biomass are part of a larger process development program.

Activity 1: Gasification Studies of Torrefied Biomass **BUDGET:** $393,290

Reaction studies with torrefied biomass will be done to determine the gasification rate and product selectivities. These studies will involve pilot plant studies with torrefied biomass at conditions representative of commercial gasification. Experiments will be designed and conducted to cover the effects of pressure, temperature, and gas composition. Knowledge of the partitioning of the S and N between the char and gasification products will be gathered since this information is required for sizing downstream equipment such as the sulfur removal equipment and flue gas cleanup equipment. Finally, the results of the previous task studies will be used to create a kinetic model to predict the amount of tar and char formed by gasification of torrefied and raw biomass. The model will be capable of evaluating gasifier design modifications effectiveness in reducing tar formation.

Outcome	Completion Date
1. Provide Product Yields From Gasification of Torrefied Biomass Report	*11/30/2012*
2. Provide Tar & Char Formation Kinetics For Torrefied Biomass Report	*7/12/2013*
3. Provide Process Model for Tar & Char Formation in Biomass Gasifiers Report	*9/20/2013*

Activity 2: Economic Cost/benefit Analysis **BUDGET: $**27,731

The combined torrefaction/gasification process will be modeled using a software process simulator package, such as ASPEN, to determine the economic impact of reduced tar and soot formation on producing synthesis grade syngas from biomass. The process simulation data will be used to quantify the reduction in both capital and operating costs associated with the reduced syngas cleanup demand resulting from reductions in tar and soot. This will be compared to the added costs associated with the use of torrefied rather than raw biomass as the gasification feedstock.

Outcome	Completion Date
1. Provide a Final Report that provides an assessment of the Advantages and Disadvantages of Torrefaction of Biomass on Gasification	*12/30/2013*
2. Present Findings in a Referred Publication and/or PhD Dissertation	*TBD*
3. Present Findings at Biomass Conference	*TBD*

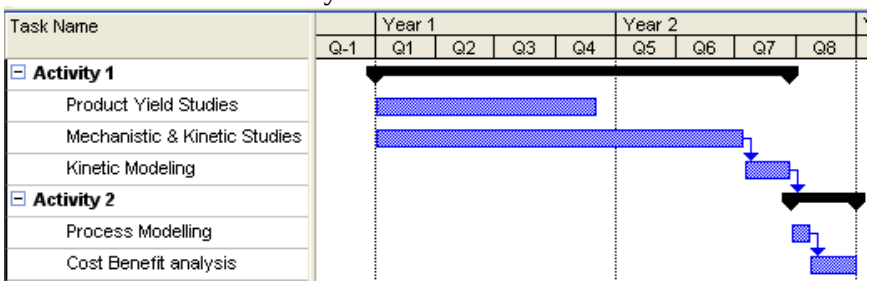
III. PROJECT STRATEGY

A. Project Team/Partners

The project team consists of SynGas Technology, LLC (SGT), the University of Minnesota, and Rural Advantage Cooperative. SGT will manage the program and be responsible for conducting the gasification pilot plant studies. Professor Lanny Schmidt, of the University of Minnesota's Chemical Engineering Department, will provide graduate students and serve as a technical advisor to the program. Graduate students will be responsible for conducting small scale experiments to determine reaction rates and mechanisms of the fundamental processes that occur in gasification. Rural Advantage Cooperative will supply cellulosic biomass and provide storage facilities of the biomass.

B. Timeline Requirements

The project is scheduled to start in July 2011. The following Gantt chart provides the overall project schedule and shows the relationship between project activities and tasks. A six month period is allowed for to account for the time to size and torrefy the biomass feedstock.



C. Long-Term Strategy and Future Funding Needs

Understanding tar formation and how to mitigate or eliminate it is a crucial step toward the implementation of economical thermochemical conversion of biomass to specification transportation fuels. SGT's long term goal is to develop a high pressure gasifier for use with biomass. To date SGT has secured more than 3.5M$ in private investment to develop gasifier technology. We estimate that a total investment of 40M$ is needed, which requires private venture capital. This program addresses a recognized development issue with major economic implications for the development of thermochemical conversion technologies. To the extent that the program provides insight to tar and soot formation, it reduces technology development risk and facilitates raising private venture capital.

2011-2012 Detailed Project Budget

INSTRUCTIONS AND TEMPLATE (1 PAGE LIMIT)

Attach budget, in MS-EXCEL format, to your "2011-2012 LCCMR Proposal Submit Form".

(1-page limit, single-sided, 10 pt. font minimum. Retain bold text and DELETE all instructions typed in italics. ADD OR DELETE ROWS AS NECESSARY. If a category is not applicable write "N/A" , leave it blank, or delete the row.)

IV. TOTAL TRUST FUND REQUEST BUDGET - Two years

BUDGET ITEM *(See list of Eligible & Non-Eligible Costs, p. 13)*	**AMOUNT**
Personnel: Program Manager/Principal Investigator, 7.9% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 40,985
Personnel: Supervisor, 5.7% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 13,677
Personnel: Senior Engineer 20+ yrs experience, 14.7% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 62,396
Personnel: Process Modeler, 2.5% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 5,529
Personnel: Chemical Engineer 10+ yrs experience, 25.0% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 66,000
Personnel: Chemical Engineer 2+ yrs experience, 9.1% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 13,678
Personnel: Laboratory Technician, 36.4% of full-time employment, 87% salary, 13% allowed benefits, 1/1/12-12/31/13, one employee	$ 37,656
Contracts: University of Minnesota - one graduate student for one year to assist with gassification studies	$ 75,000
Contracts: University of Minnesota - one graduate student for one year to assist with tar/soot gassification studies	$ 75,000
Equipment/Tools/Supplies: Lease of High Pressure Cell for Thermograimetric Analyzer required for high pressure testing relating to gasification rates of torrefied biomass	$ 10,000
Equipment/Tools/Supplies: Lab gas such as CO2, nitrogen, etc for Thermogravimetric Analyzer	$ 4,000
Equipment/Tools/Supplies: Consumable parts and machining expenses for pilot plant operation	$ 9,100
Equipment/Tools/Supplies: Lab gas for gassification studies	$ 8,000
TOTAL ENVIRONMENT & NATURAL RESOURCES TRUST FUND $ REQUEST	$ 421,021

V. OTHER FUNDS

SOURCE OF FUNDS	**AMOUNT**	**Status**
Other Non-State $ Being Applied to Project During Project Period: These funds are used to cover the cost of raw biomass, storage, drying, sizing, and torrefaction of the biomass. Source: G.D.O., Inc. d/b/a Gradient Technology	$ 256,606	*Secured*
Other State $ Being Applied to Project During Project Period:	$ -	
In-kind Services During Project Period:	$ -	
Remaining $ from Current ENRTF Appropriation (if applicable):	$ -	
Funding History: Source: G.D.O., Inc. d/b/a and other private investors	$ 3,500,000	

V. PROJECT MANAGER QUALIFICATIONS/ORGANIZATIONAL DESCRIPTION

The project manager for the proposed effort is Mr. Duane Goetsch. Mr. Goetsch is the CTO of SynGas Technology, LLC (SGT) and is responsible for oversight of all SGT development programs. In addition, Mr. Goetsch is the principal investigator for the development of high-pressure gasification systems for biomass at SGT. SGT is a small business located in Elk River, Minnesota. SGT personnel are experts in gasification and fuels production technology, having extensive experience in fuels technology research, development, and commercialization.

Education

Mr. Goetsch received a B.S. in chemical engineering from the University of Illinois, Champaign-Urbana in 1978, where he graduated with High Honors. He was the recipient of the Donald Donald E. Eisele Award for outstanding undergraduate performance in Chemical Engineering, a member of Tau Beta Pi, President of the student AIChE chapter, and was awarded a DOE fellowship to conduct research in reprocessing nuclear fuels at Argonne National Laboratories.

In 1990, Exxon Research and Development Laboratories sponsored his graduate work at the University of Minnesota on the partial oxidation of alkanes at microsecond contact times to produce oxygenates at the University of Minnesota under direction of Professor Lanny Schmidt, and his work was featured in *Science* and *Chemical & Engineering News.* He also received a Fellowship from the Naval Research Laboratories. In 1994 he founded *Gradient Technology* with Dr. Nancy Dickerson and Dr. Kym Arcuri.

Employment History

2008 – Present SynGas Technology, Chief Technical Officer and Principal Investigator for development of high pressure gasifiers for biomass, Elk River, MN.
1994 – 2008 President and Chief Technical Officer of Gradient Technology, Elk River, MN.
1990 – 1995 Research Assistant, University of Minnesota, Minneapolis, MN.
1978 – 1994 Senior Engineer, Exxon Research and Development Laboratories, Baton Rouge, LA.
1978 Teaching Assistant (Chemistry), University of Illinois, Champaign-Urbana, IL.
1977 Research Fellow, Argonne National Laboratory, Argonne, IL.

Relevant Professional Experience

• Co-founder of *Gradient Technology* with 30 years of industrial energy related research experience including 13 years of industrial applied research and development in petroleum and chemical processing at Exxon Research & Development Laboratories.

• Principal investigator for development of a high-pressure fast fluidized gasifier used in Exxon's Gas-to-Liquids project. Responsibilities included all aspects of fluidization engineering, catalyst development, reaction kinetics, and injector dynamics. Culminated in design and construction of >10 MM$ demonstration plant (high pressure gasifier).

Appointments, Awards, Patents

• Appointed by the Governor of Minnesota to "Governor's Clean Energy Technology Collaborative" in September 2008and chaired the biofuels subcommittee.

• Under his leadership *Gradient Technology* won the 2001 National Tibbitts Award for its outstanding SBIR contributions. Under his tenure *Gradient Technology* also received Minnesota Project Innovations Excellence award in 2002 and have consistently received accommodations for Gradient's success in being awarded SBIR and BAA programs.

• Holder of 12 US patents and more than 10 pending in catalysis, petroleum processing technology, explosives and chemicals. Has authored or co-authored 13 refereed papers, 2 ACS Monograph Series book chapters on catalysis, several presentations at national symposia in chemistry and chemical engineering.