



Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-196

Proposal Title: Electricity Generation from Glycerol - Minnesota Biodiesel Waste

Project Manager Information

Name: Jacob Swanson

Organization: Minnesota State Colleges and Universities - Minnesota State University Mankato

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Project Basic Information

Project Summary: Modification and field testing of an plasma gasification system to create renewable on-site electricity generation from crude glycerol, a soybean derived biodiesel waste product. Conduct engineering and economics analyses.

Funds Requested: \$679,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Air Quality, Climate Change, and Renewable Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Narrative

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

The United States is the world leader in biodiesel production, and Minnesota is currently the tenth largest producer of biodiesel in the US at 85.5 million gallons a year with that quantity expected to rise. The biodiesel production process in Minnesota generates more than 6 million gallons of crude glycerol yearly as a result. This byproduct is of little value (\$0.31 - \$1.04 per gallon) and has minimal uses due to its impurities. The current large markets available for the application of crude glycerol are limited to further refinement for the use in cosmetics and pharmaceuticals or as a supplement in livestock feed. These markets are currently over-saturated, forcing producers to search for new ways to dispense the waste material. Finding new uses for crude glycerol is an ongoing priority for the Agricultural Utilization Research Institute, the Soybean Growers Association, and the biodiesel industry. If new markets for this byproduct are not found, it may become more cost-effective for producers of crude glycerol to dispose of it. There is interest in using crude glycerol as a potential alternative source of renewable energy, and the gasification process does not require any further processing.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

The gasification of biomass feedstocks is a carbon-neutral way of producing a combustible gas that can be used to produce electricity. The Twin Cities Engineering (TCE) Program currently has a microwave plasma system that has been designed for the gasification of powdered biomass and a Honda GX200 engine-generator that has been modified to run on gaseous fuels. These systems will be combined and modified. The resulting system will allow exploration of the use of crude glycerol as an alternative energy source. Specifically, we will modify our current feedstock delivery system to atomize the liquid crude glycerol before it is passed through the high-temperature microwave plasma torch. This process breaks the glycerol down into its combustible gaseous molecules (H₂, CO, CH₄), creating syngas. The syngas will then be used to fuel a modified internal combustion engine to produce electricity via a generator. The microwave plasma and engine-generator systems have inherent energy losses that can be recovered through integration with a biodiesel manufacturing process. The recoverable losses will be calculated to determine the net energy output. Upon completion of the modifications and integration of our current systems, a consolidated unit will be evaluated for six months on a Minnesota farm producing biodiesel.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

Syngas is a clean-burning renewable fuel source that can be used as a substitute for natural gas, fuel oil, or propane. Using the crude glycerol as a feedstock source of syngas will provide a valuable use for the biodiesel byproduct. Our work will provide Minnesota farms and biodiesel producers with a new market for their byproduct. This new market will eliminate the need for further purification of glycerol, thus, eliminating the environmental impact of the refinement processes. It will also provide Minnesota farms and biodiesel producers a source of renewable energy, reducing the need to dispose of the waste product.

Activities and Milestones

Activity 1: Modify and test existing systems to generate electricity from microwave plasma gasification of glycerol waste from biodiesel production.

Activity Budget: \$340,000

Activity Description:

Twin Cities Engineering has previously created a microwave plasma gasifier along with a modified gas engine-generator to generate electricity from the synthesis gas produced by gasification. For this activity, the existing components of the microwave plasma gasification system will be modified to accept the crude liquid glycerol, a waste byproduct of biodiesel production. These components include the microwave plasma gasification system as well as the existing feedstock delivery system that is currently optimized for solid feedstocks. The feedstock delivery system will be modified to accept a liquid feedstock and to incorporate a heating element and pump for the glycerol to flow properly for atomization. Once the modifications to the feed delivery system and microwave plasma gasification system are completed, the existing modified gas engine-generator will be modified to accept the syngas produced by the microwave plasma system, and the two systems will be integrated to be capable of generating electricity. Once this has been done, testing will be conducted to learn the optimal settings for use of the feed system, microwave plasma gasifier, and engine-generator systems for larger scale testing, along with determining if purification of the glycerol is necessary prior to use for gasification.

Activity Milestones:

Description	Completion Date
Modifications to the microwave plasma system are completed, and system is prepared for glycerol gasification.	2021-12-31
Microwave plasma gasifier is integrated with modified gas engine-generator for electricity generation.	2022-05-31
Testing using varying purities of glycerol feedstock is completed, and electricity is generated.	2022-12-31

Activity 2: Field test electricity generation from glycerol through microwave plasma gasification for six months in an end-user setting.

Activity Budget: \$339,000

Activity Description:

A second integrated microwave plasma gasification system will be developed in the Twin Cities Engineering labs for use on a Minnesota farm. This second system will be intended for longer scale testing than its predecessor and will be fabricated to reflect that intent. The second system will be retrofitted to a storage tank for the liquid crude glycerol and will also be connected to a modified gas engine-generator. This second integrated microwave plasma electricity generation system will be moved from the Twin Cities Engineering labs to the Minnesota farm to test the system's functionality in an end-user setting for an extended time, six months. The system will be stored and operated on the Minnesota farm with periodic maintenance and check-ins performed by Twin Cities Engineering to verify the system is working as intended. Operating instructions and safety procedures will be developed to ensure the system is not damaged during the field testing. The intent behind testing at a Minnesota farm location is to ensure the system works for an extended period of continuous use. To determine the efficiency of the system, an energy balance calculation will be completed, including analysis of recoverable waste energy losses.

Activity Milestones:

Description	Completion Date
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Energy balance calculation is completed, showing efficiency of the system and analysis of recoverable losses.	2022-12-31
Minnesota farm location and partner is determined for field testing.	2022-12-31
Second microwave plasma gasification system is developed for field use, and operation instructions are created.	2023-12-31
Field test the microwave plasma gasification system on the Minnesota farm for six months.	2024-06-30

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this be funded?

The main goal of this project is to develop viable on-site electricity generation capability using waste byproducts. Following completion of this grant the results of this process will be disseminated to the public via scientific journals, as applicable, and content will be publicly available on the Twin Cities Engineering webpage. Future steps include a three-pronged approach. First, upscaling the current system and increasing the efficiency through integration with manufacturing processes allowing for the recovery of waste energy. This increases electricity generation capacity, thereby providing a larger benefit to biodiesel producers and farmers. Second, determine if additional waste products, such as manure and wheat byproducts, are viable for gasification. Third, using the above advancements and insight, create an economically viable product that can be brought to market with industry partners. A wide range of private and publically available funding will be sought to support future efforts.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Assessment of Urban Air Pollution	M.L. 2017, Chp. 96, Sec. 2, Subd. 07b	\$700,000

Project Manager and Organization Qualifications

Project Manager Name: Jacob Swanson

Job Title: Associate Professor of Engineering

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Jacob Swanson is an Associate Professor of Engineering in the Twin Cities Engineering Program in the Department of Integrated Engineering at Minnesota State University Mankato. He is also an Adjunct Associate Professor in the Department of Mechanical Engineering (ME) at the University of Minnesota. He was previously a Research Associate in the Department of Engineering at the University of Cambridge, UK and before that, a graduate of UMN's ME Department. Prof. Swanson is internationally recognized for his work on emissions from engine combustion engines. He has published 38 papers and given about 100 conference presentations on these topics. He is currently advising about 30 students as part of his ENGR Design course. He has 3-4 other external projects supporting about eight undergraduate students. He annually supports, by co-advising, on average 1-2 graduate students in the Particle Technology Laboratory and Engine Research Labs at the University of Minnesota. For the past three years he has worked on a project titled "Microwave plasma gasification" that seeks to generate electricity from waste wood by creating and combusting syngas in an internal combustion engine. The technical achievements in this project will be leveraged to aid in the success of the proposed work.

Organization: Minnesota State Colleges and Universities - Minnesota State University Mankato

Organization Description:

Twin Cities Engineering (TCE) is a program of the Department of Integrated Engineering of Minnesota State University, Mankato. TCE has the purpose of expanding the pool of qualified engineers in the Twin Cities Metro area by establishing an affordable, accessible, and unique option for the region's engineering students. TCE offers an inclusive and innovative learning experience that has attracted non-traditional students and veterans at a higher rate than traditional students. The BSE degree program includes several features that differentiates it from traditional engineering degree programs.

TCE addresses the entire learning experience and not simply one component of the curriculum. Five features, designed to produce desired attributes in BSE graduates, are as follows.

- Trans-disciplinary thinking
- Industry-sponsored, project-based-learning
- Experiential learning in context
- Competency-based assessments
- Significant exposure to professionalism, design, creativity, and innovation

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
Personnel								
Associate Professor		Supervise undergraduate research assistances			36%	0.75		\$156,500
Undergraduate research assistants		Design, fabrication, experimental, results analysis			8%	7.5		\$215,000
							Sub Total	\$371,500
Contracts and Services								
TBD	Professional or Technical Service Contract	Design and installation of a intrinsically rated ventilation system in the Twin Cities Engineering Rooms that is specially required to vent syngas out of the rooms. Contractor also provides electrical service on the parking ramp such that all components of the system can be powered.				0.5		\$50,000
							Sub Total	\$50,000
Equipment, Tools, and Supplies								
	Tools and Supplies	Consumable supplies (misc fittings, hoses, connectors, gases)	Consumables and supplies are needed as part of any engineering effort that requires fabrication and testing					\$5,000
	Equipment	Materials and fabrication expenses associated with the fabrication of an plasma inlet - Design iteration 1	The plasma inlet is a component designed for this project which transfers liquid glycerol to the plasma system and then atomizers it so it can be reacted					\$5,000
	Equipment	Materials and fabrication expenses associated with the fabrication of an plasma inlet - Design iteration 2 (multiple iterations needed).	The plasma inlet is a component designed for this project which transfers liquid glycerol to the plasma system and then atomizers it so it can be reacted					\$5,000

	Equipment	Materials and fabrication expenses associated with the fabrication of an plasma inlet - Design iteration 3 (multiple iterations needed).	The plasma inlet is a component designed for this project which transfers liquid glycerol to the plasma system and then atomizers it so it can be reacted					\$5,000
	Tools and Supplies	Consumable supplies (misc fittings, hoses, connectors, gases)	Consumables and supplies are needed as part of this engineering effort that requires fabrication and testing					\$2,500
							Sub Total	\$22,500
Capital Expenditures								
		All components required for microwave plasma generator (power supply, microwave generator, cooling, waveguides, misc). Includes components to modify existing system and build a second modified for use on a farm per the proposal. System consists of 20+ components that are engineered to work together, most cost less than \$5,000. Some are purchased off the shelf, some are designed and fabricated	A microwave plasma generator is used to create syngas from glycerol which is combusted in an internal combustion engine to generate electricity					\$100,000
		Syngas engine test stand. Includes components to modify existing test stand and build a second modified for use on a farm per the proposal. The engine test stand consists of 20+ components that are engineered to work together, most cost less than \$5,000. Some are purchased off the shelf, some are designed and fabricated	The engine burns syngas and produces electricity					\$125,000
							Sub Total	\$225,000
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								
	Miles/ Meals/ Lodging	Travel by faculty and students to on-site location of electricity generation	The proposal includes running our device at a farm in MN (to be determined) for 6 months. We anticipate many trips back and forth.					\$10,000

			For some trips, a truck will have to be rented to transport plasma system back and forth to our location for possible repairs and maintenance.					
							Sub Total	\$10,000
Travel Outside Minnesota								
							Sub Total	-
Printing and Publication								
							Sub Total	-
Other Expenses								
							Sub Total	-
							Grand Total	\$679,000

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	-
Non-State				
			Non State Sub Total	-
			Funds Total	-

Attachments

Required Attachments

Visual Component

File: [ebbae406-491.pdf](#)

Alternate Text for Visual Component

Electrical Generation From Minnesota Biodiesel Waste. There is a bottle labeled "Biodiesel Waste - Glycerol." This bottle goes into the Microwave Plasma Gasification System. It produces syngas fuel which is then put into an engine which produces electricity and ultimately Minnesota (including biodiesel soybean farmers) by increasing the amount of renewable energy produced by the State

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

No

**BIODIESEL
WASTE
(GLYCEROL)**

**MICROWAVE
PLASMA
GLYCEROL
GASIFICATION
SYSTEM**

**ELECTRICAL GENERATION
FROM MINNEOSTA BIODIESEL
WASTE**

SYNGAS FUEL

**ELECTRICITY
GENERATION**

**HELP THE AGRICULTURAL INSTITUTIONS AND BIODIESEL
INDUSTRIES IN MINNESOTA**



