Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-261

Proposal Title: Increasing Efficiency Of Methane Digesters

Project Manager Information

Name: Kyle Costa

Organization: U of MN - College of Biological Sciences

Office Telephone: (612) 624-5375

Email: kcosta@umn.edu

Project Basic Information

Project Summary: This proposal investigates low-cost additions to methane digesters that can increase electricity generation. We will focus on using resources that are compatible with existing methane digesters common to cold climates.

Funds Requested: $148,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Small Projects (H)

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

Project Location

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

Statewide

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

Statewide

When will the work impact occur?

In the Future

Narrative

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

Methane is the main component of natural gas and a potent energy source. Methane can be produced "on-site" using methane digesters. Digesters are used statewide by individuals, industry, and municipalities and are powered by input waste such as wastewater or manure that is converted to methane by a community of microorganisms. The ultimate goal is capture and use of this methane as a power source (i.e. converting gas to electricity). These digesters enable continuous and reliable electricity generation through recycling waste. In an effort to increase accessibility to methane digesters, Minnesota has maintained the State Methane Digester Loan Program since 1998, demonstrating a commitment to this technology. Through this program, digesters have been installed statewide.

Digesters are currently used, but increasing efficiency has proved challenging. Identifying low cost improvements that are compatible with existing systems has been especially difficult. We hypothesize that simple additions to current digesters can improve methane production. One difficulty is that microorganisms necessary for methane production remain suspended in the liquid phase of digester systems and are lost as water flows out of the system. Attachment of these organisms to particles that remain in the digester can increase methane production by minimizing biomass loss.

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.

We propose a study to investigate how the addition of select compounds can improve methane production rates in laboratory scale methane digesters. Current evidence suggests that methane forming organisms will efficiently attach to some materials. Of particular interest is that attachment to metals is particularly efficient. Within the state of Minnesota, minerals that contain metals are abundant, easy to acquire, and low cost. For example, taconite ore is plentiful and has properties similar to surfaces that methane forming organisms are known to adhere to.

We will employ laboratory scale systems to test the ability of methane forming organisms to adhere to low-cost materials such as glass, clay (mined in the Minnesota River Valley), silica sand (mined in southeastern Minnesota), or taconite. After identifying a variety of materials that allow attachment of methane forming organisms, we will test the efficiency of these compounds in improving methane production in laboratory scale methane digesters. At this stage of the project, we will work primarily with well-characterized organisms; however, the ultimate goal is to expand work to include working, currently deployed methane digesters across the state.

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?

Through the two-year project period, we will test the ability of several mineral compounds to increase the efficiency of methane production through waste digestion. If successful, addition of these cheap and abundant compounds can be expanded to work with current state infrastructure to increase energy output of the digestion process. The goal is to develop a procedure to increase methane production using abundant and low-cost materials, which will lower overall operating costs on a per kWh basis.

Activities and Milestones

Activity 1: Test the ability of methane forming organisms to attach to minerals so they are retained in digesters

Activity Budget: $36,222

Activity Description:
Model methane forming organisms will be tested for their ability to efficiently attach to a variety of minerals (substrates). We will also test the effect of temperature on the attachment of these organisms. Existing systems can be run under ambient temperature or heated – our experiments will run a range of temperatures to reflect these differences. These initial experiments will be performed under controlled laboratory conditions. A variety of substrates such as taconite, glass, clay, silica sand, and metals will be used.

Several different methane forming organisms are often present in methane digesters. In order to find substrates that allow for efficient attachment of all these groups, experiments will be performed with pure cultures of several organisms. In some cases, we have mutant strains that will be used as attachment controls. If necessary, a mixture of substrates will be used to maximize attachment. To measure attachment, we will use established procedures to specifically quantify biomass on substrate surfaces. We will also directly measure methane production rates in these experiments to assess the efficiency of methane generation per gram of biomass.

Activity Milestones:

Description	Completion Date
Experiments at 37 °C with at least 5 methane formers on 5 substrates	2021-08-31
Experiments at 22 °C	2021-10-31
Experiments at 4 °C	2021-12-31

Activity 2: Test enhancement by minerals in a laboratory scale methane digester.

Activity Budget: $111,778

Activity Description:
Once we identify substrates that allow efficient attachment of methane forming organisms, we will grow both pure and mixed methane forming cultures in a laboratory scale, continuous flow reactor. These growth experiments are time-consuming and will occur over the last ~75% of the project period. We will test the ability of substrates to retain biomass by measuring methane production rates and total biomass under different reactor flow rates. We will also monitor the total biomass that is lost from the reactor outflow. We will test the efficiency of methane production when the reactors are fed with a variety of carbon sources (e.g. manure, rumen fluid, ethanol, small organic acids, etc…). Reactors will be run under optimal temperature conditions as determined in Activity 1.

One significant advance from activity 2 is that we will transition from work with pure cultures of methane forming organisms to working with “natural communities.” These experiments will better reflect the situation in methane digesters that are currently deployed. We will use either cattle manure, natural sediments where methane forming organisms are found, or fluid from an existing methane digester as the source of these natural methane forming communities.

Activity Milestones:

Description	Completion Date
Use a continuous flow system to test substrates in retaining organisms	2022-08-31
Use the continuous flow system to test natural communities	2023-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Daniel Bond	University of Minnesota	Daniel Bond, PhD (professor, Department of Plant and Microbial Biology, University of Minnesota): Prof. Bond is an expert in interactions between living systems and iron containing minerals.	Yes

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 proposed work is the start of a long-term project. If successful, the results from this project would be highly impactful. The proposed work complements current Department of Defense funded efforts where our group is studying the molecular basis of biofilm formation in methane forming organisms. Future funding for the proposed work could come from a variety of sources, including the Department of Energy, Department of Defense, the Advanced Research Projects Agency – Energy, or private foundations with an interest in bioenergy.

Project Manager and Organization Qualifications

Project Manager Name: Kyle Costa

Job Title: Assistant professor

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

Kyle Costa, PhD (assistant professor, Department of Plant and Microbial Biology, University of Minnesota): will oversee the project and manage the team. Dr. Costa received his PhD from the University of Washington in 2013 and worked for four years through a postdoctoral fellowship at the California Institute of Technology before moving to the University of Minnesota.

Dr. Costa's laboratory studies the physiology, metabolism, and genetics of methane producing organisms. Dr. Costa has over ten years of experience working with these organisms and developing a variety of laboratory tools to facilitate their study. Research funding for the lab comes from the US Department of Energy, the US department of Defense, and the University of Minnesota's Biotechnology Institute.

The Costa laboratory is housed in the Biological Sciences Center at the University of Minnesota. The laboratory contains the equipment necessary to carry out the project, including variable temperature incubators, anaerobic chambers, two 1-liter continuous cultivation fermentation vessels, autoclaves, and the necessary equipment for analytical measurements (microplate reader, UV-Vis spectrophotometer, Gas Chromatograph, etc…).

Organization: U of MN - College of Biological Sciences

Organization Description:

This work will take place in ~1,500 sq. ft. of laboratory space at the University of Minnesota in the Department of Plant and Microbial Biology. The Department of Plant and Microbial Biology is a basic science department at the University of Minnesota – the state land grant institution. The university provides a range of "core facilities" to supplement the research efforts ongoing in individual laboratories. The University of Minnesota Sponsored Projects Agency is authorized by the Board of Regents to manage agreements through the LCCMR program.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Researcher 1		Perform experiments, analyze results			24%	2		$93,183
Kyle Costa, Principal Investigator		Oversee project, design and perform experiments, analyze results			26.7%	0.12		$12,360
Daniel Bond, Co-Principal Investigator		Oversee project, design experiments, analyze data			26.7%	0.06		$9,647
							Sub Total	**$115,190**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	General Operating Supplies	Day-to-day supplies for experiments. Includes plastics, reagents, gloves, etc...					$28,810
	Tools and Supplies	Lab services	University of Minnesota genomics center. For sequencing services.					$2,000
							Sub Total	**$30,810**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								

							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Sponsored Publications	Publication of results in scientific journals					$2,000
							Sub Total	**$2,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$148,000**

Classified Staff or Generally Ineligible Expenses

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

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Indirect costs for this proposal, though not allowed, are listed as in-kind contribution of 55% MTDC which is the Federally Negotiated rate with the U of MN. The indirect is proportionate to the awarded funds at a rate 55% so if the award is reduced the F&A would be reduced.	To pay for administrative and facility expenses for this project	Secured	$81,394
			Non State Sub Total	**$81,394**
			Funds Total	**$81,394**

Attachments

Required Attachments

Visual Component

File: 227cc5fa-c87.pdf

Alternate Text for Visual Component

Comparison between existing methane digester technology and proposed improvements through addition of attachment substrates. In a system supplemented with substrates for attachment, microorganisms are more efficiently retained in the reactor vessel. This results in increased methane production and more energy available for downstream processes.

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

Yes,

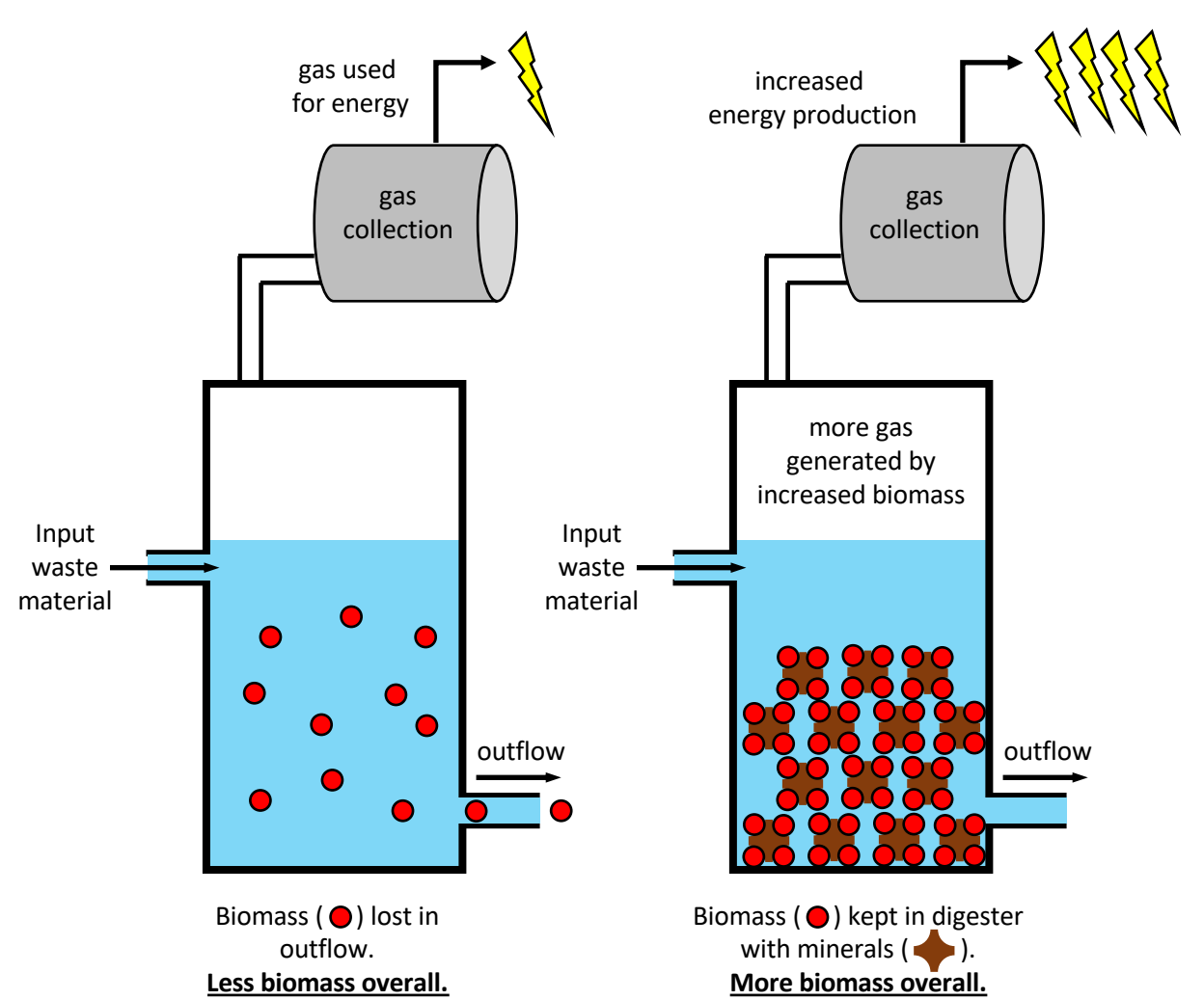
- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration


gas used
for energy
gas
collection
Input
waste
material
outflow
Biomass ( ) lost in
outflow.
Less biomass overall.
increased
energy production
gas
collection
more gas
generated by
increased biomass
Input
waste
material
outflow
Biomass ( ) kept in digester
with minerals ( ).
More biomass overall.
Current digester systems
Digester with biomass retention