Environment and Natural Resources Trust Fund

2022 Request for Proposal

General Information

Proposal ID: 2022-053

Proposal Title: Advanced anaerobic digestion for organic waste utilization

Project Manager Information

Name: Roger Ruan

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: Overcome technical issues faced by anaerobic digestion industry through blending and pretreatment of organic wastes, adjusting carbon/nitrogen ratio, optimizing operating parameters, effluent processing, ensuring complete treatment /utilization of wastewater.

Funds Requested: $523,000

Proposed Project Completion: June 30 2025

LCCMR Funding Category: Water Resources (B)

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?

During the Project and In the Future

Narrative

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

Anaerobic digestion (AD) has been scaled up to commercial operations in the United States. However, according to the "American Biogas Council" full potential for this technology is at least 10 times the current production, not only for renewable fuels, but also for wastewater treatment applications. Some organic wastes are difficult to ferment in their raw form, and blending with other wastes is needed to achieve proper carbon/nitrogen ratios for optimum bio-methane production. Research is needed to demonstrate improved mixtures of organic wastes, including dairy and hog manures, chicken and turkey litters, and/or human food wastes. Also, pretreatment methods, such as thermal-hydrolysis and ammonia stripping, will improve and optimize the preparation of these wastes for AD processing, and reduce tons of organic wastes being sent to landfills. The bio-methane produced can be used for electrical power, or upgraded as vehicle fuel. However AD plants also generate millions of gallons of liquid effluent containing ~20% of the incoming, unutilized wastes; these remaining wastes can be further utilized in aerobic fermentations, and hydroponics for food production or algae cultivation for energy and chemical production.

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.

To address the above issues, a 20 Liter (5 gallon) AD fermenter will be used to test a variety of waste feedstock mixtures to improve and optimize AD process reliability and bio-methane production. In addition, pretreatment methods, such as thermal hydrolysis and ammonia stripping, will be used to demonstrate improved digestibility of waste mixtures, and reduce the remaining organic materials in the AD effluent. The effluent from this pilot fermenter will be used to support additional development of downstream processes, such as hydroponic food production and algae biomass production. Additional cleaning steps such as biochar filtration to remove remaining pollutants prior to discharge or reuse of the water will also be investigated. The goal of these downstream processing steps is to ensure full utilization of remaining organic components in the effluent, and minimize the resulting water COD before discharge to a WWTP or the environment. So, organic waste mixtures, pretreatment methods, improved productivity of bio-methane, and reduced residual organic wastes in the AD effluent, will all be addressed to support commercialization of this promising technology.

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?

The overall goals of this proposed program include several benefits for society at large. The first important goal is to utilize a wide range of organic wastes, which are currently added to annual tons of wastes in landfills, and/or higher COD loadings in WWTP's nationwide, resulting in higher operating costs. These organic wastes can, instead, generate renewable energy via bio-methane for electrical power, or RNG for vehicle fuel, and displace fossil fuel use. Residual pollution in AD plant effluent will be minimized by being utilized in downstream processes.

Activities and Milestones

Activity 1: Design and build anaerobic digester, identify and collect a variety of organic wastes from agriculture and commercial sources.

Activity Budget: $250,000

Activity Description:
Identify and collect organic wastes from local farms (dairies, hogs, turkeys, chickens) and local restaurants, groceries, and institutional food facilities. Blend these wastes appropriately into a mixed feedstock, and carry out proximate and ultimate analyses to assure a proper mixture of ingredients to support healthy anaerobic bacteria culture; this is not a one-time activity, but an ongoing process to continuously supply the fermenter for the life of the project. We will include challenging feedstocks that need special attention, to assure they do not continue to be discarded in landfills, or simply added to WWTP influent. Test and integrate pretreatment methods of the feedstock mixture to maximize the utilization of the organic wastes during AD processing, and minimize the remaining COD in the effluent stream.

Activity Milestones:

Description	Completion Date
A bench scale anaerobic digester system will be developed and operational	June 30 2022
Available organic waste streams are identified with the assistance of state and county DNR agents	December 31 2022
Waste stream mixtures are analyzed and formulated; pretreatment methods are developed and evaluated	June 30 2023
The performance of the anaerobic digester is evaluated and optimized	December 31 2023

Activity 2: Collect and evaluate AD effluent, and integrate with downstream processing.

Activity Budget: $206,925

Activity Description:
As Activity 1 continues to document the productivity of the biogas and bio-methane, Activity 2 will begin to address the effluent stream from the digester. The volume, COD, proximate and ultimate analyses, will be measured for the effluent. Its suitability for supplying nutrients for aerobic and hydroponic/algae processing will be evaluated. After being used in these downstream processes, the final effluent analyses such as COD, volatile solids, and dissolved solids, will be evaluated. Biochar filtration will be used to further remove pollutants if necessary. The goal of Activity 2 is to demonstrate that the final effluent, after AD and additional downstream processing, can be discharged into a WWTP with minimal COD, or even discharged to a local river within standard environmental WWTP discharge limits.

Activity Milestones:

Description	Completion Date
AD effluent is analyzed	December 31 2023
Downstream processes are developed and evaluated	June 30 2024
Final treated AD effluent is evaluated against typical WWTP discharge standards	December 31 2024

Activity 3: Collect and analyze all data from Activities 1 and 2, scale up process, and demonstrate the system to the stakeholders

Activity Budget: $66,075

Activity Description:
The mass and energy balance data, together with analytical data, will be used to evaluate the environmental and

economic performance, in a hypothetical scaled-up commercial model. This evaluation will provide good assessment of the environmental impact of the proposed technology. Further R&D efforts and commercialization strategy will be recommended. The results will be published in academic journals, and in industrial journals, recommended by the American Biogas Council, for commercial consideration.

Activity Milestones:

Description	Completion Date
Mass and Energy balances, and analytical results are documented	June 30 2025
Commercial scaled-up mass and energy balances, economic analysis, capital costs are estimated	June 30 2025
Further R&D and commercialization strategy will be recommended in the final project report	June 30 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Paul Chen	University of Minnesota	Co-PI	No

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 improved anaerobic digestion will promote utilization of organic wastes. Successful development and implementation of the proposed technology will reduce these wastes and produce renewable fuels to displace the use of fossil fuels and address climate change, and reduce current pollution and groundwater contamination. The growth of the commercial anaerobic digestion industry will create jobs for US workers, and contribute to local economy. The success of the proposed project will raise significant interests from the relevant industries, public, and government agencies. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources	M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$1,000,000
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	$509,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

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

Dr. Roger Ruan, Professor and Director of Graduate Studies, Department of Bioproducts and Biosystems Engineering, and Director of Center for Biorefining at University of Minnesota, is a Fellow of ASABE and a Fellow of IFT. Dr. Ruan's research focuses on renewable energy and environment technologies for sustainable development and circular economy. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) pyrolysis and gasification, airborne and other pathogen disinfection and pollutant control, catalysis, non-thermal plasma, and nitrogen fixation, etc. He is a top-cited author with an h-index of 69, i10-index of 301, and over 19,000 citations. He has supervised over 75 graduate students, 140 post-doctors, research fellows, and other engineers and scientists, and 21 of his Ph.D. students and post-doctors hold university faculty positions. He has also been invited to give over 300 keynote lectures, invited symposium presentations, company seminars, and short courses. Professor Ruan has received and managed over 200 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He has served as guest editor or editorial board member of Bioresource Technology, Renewable Energy, Engineering, Applied Catalysis and Chemical Engineering, Journal of Food Process Engineering, The Open Plasma Physics Journal, and Associate Editor of Transactions of ASABE, Engineering Applications in Agriculture, and Transactions of

CSAE, and Chairman of Editorial Board and Editor-in-Chief of International Journal of Agricultural and Biological Engineering, etc. His earlier LCCMR funded projects have resulted in several patented technologies which have been successfully licensed to the industry. Therefore, he has the technical expertise and project management experience to ensure the execution of proposed projects.

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Organization Description:
The Center for Biorefining is a University of Minnesota research center affiliated with the College of Food, Agricultural and Natural Sciences and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research and provide education on science and technology for environment protection and circular economy; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs are founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Professor/Faculty		PI - summer salary			36.5%	0.12		$30,285
Professor/Faculty		Co-PI - contract faculty			36.5%	0.24		$66,920
1 Graduate Research Assistant		Researcher			45%	1.5		$150,951
Post doctoral researcher		research			25.4%	3		$191,887
							Sub Total	**$440,043**
Contracts and Services								
University of Minnesota	Internal services or fees (uncommon)	lab services				0		$18,000
equipment manufacturer	Professional or Technical Service Contract	maintenance and repair				-		$6,000
							Sub Total	**$24,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	Materials and lab supplies including chemicals for analysis, reagents, bacteria strains, trace fertilizers, pH testing and control, consumable supplies for analytical instruments, glassware, etc.	For running experiments and operating the systems.					$26,521
	Equipment	Components for fabrication of experimental apparatus and demonstration unit, including AD reactors, heating and temperature control units, ammonia stripping reactor, vacuum pump and control unit, mixer, temperature sensors, pressure sensors, etc.	To fabricate experimental apparatus and small system for running experiments, conducting performance analysis, and demonstration					$30,000

							Sub Total	**$56,521**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	12 one-day 3-person trips, 100 miles each round trip ($0.56/mile), meals @$49/person	Visit animal farms, collect and transport samples					$2,436
							Sub Total	**$2,436**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$523,000**

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				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Optional Attachments

Support Letter or Other

Title	File
Institutional Approval for Submission	7cb93ee7-44b.pdf
Visual graphic	28baeed0-a25.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have potential for royalties, copyrights, patents, or sale of products and assets?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

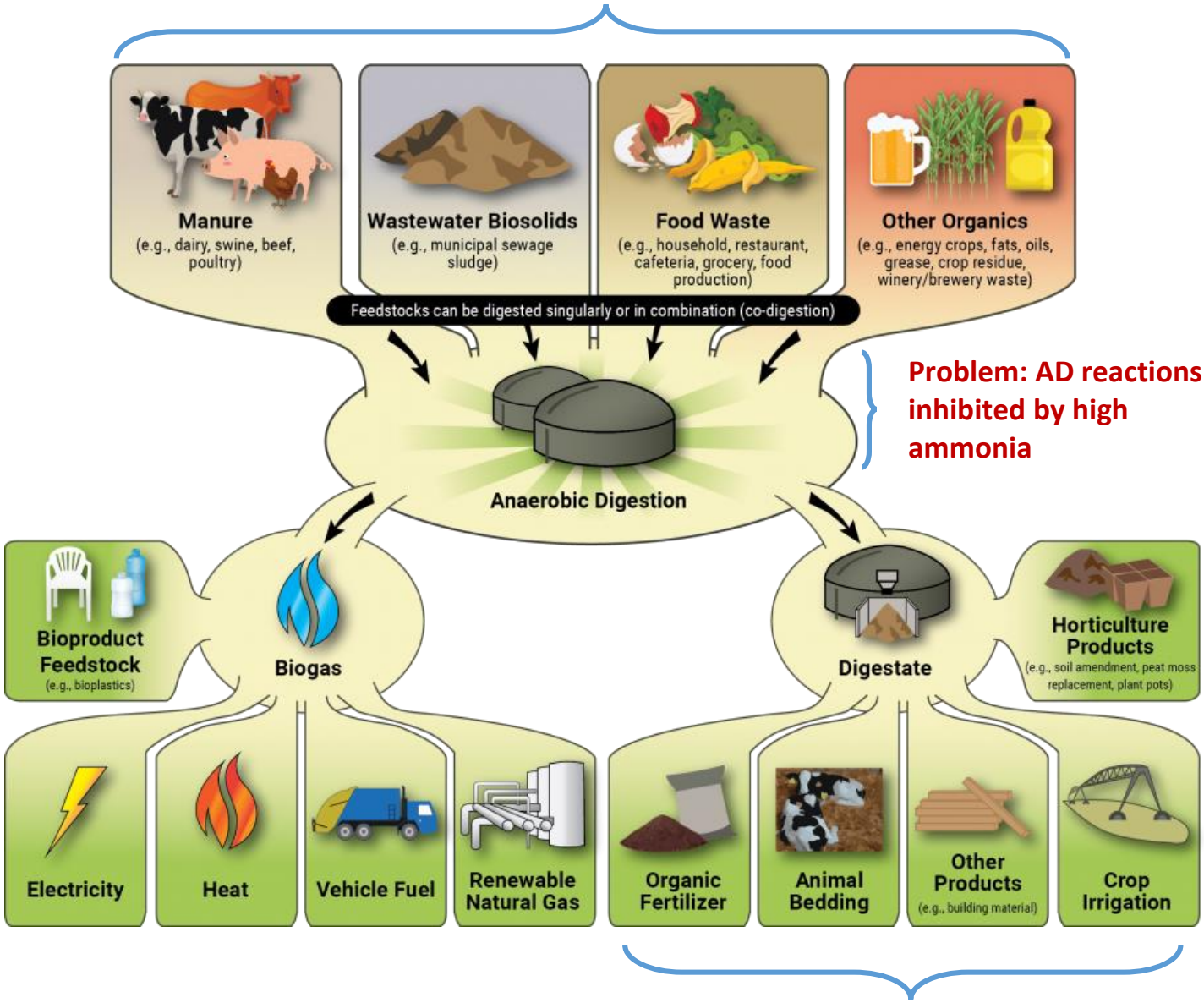
Yes

Does the organization have a fiscal agent for this project?

No

Advanced anaerobic digestion for organic waste utilization

Problem: proper carbon/nitrogen ratios of feedstock



Problem: AD reactions inhibited by high ammonia

Problem: application of AD digestate/effluent causes surface and ground water pollution

Proposed Solutions

- Mixed feedstocks
- Pretreatment of feedstock
- Stripping ammonia
- Cleaning of effluent through utilization and biochar filtration