Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-168

Proposal Title: Integrating Biological-Carbon Capture and Microalgae for Sustainable Biofuel Production

Project Manager Information

Name: Veluchamy Chitraichamy

Organization: U of MN - WCROC

Office Telephone: (320) 589-1711

Email: chitr012@umn.edu

Project Basic Information

Project Summary: This study will investigate the potential use of swine wastewater as a growth medium for the microalgae, with a focus on biological carbon capture and sustainable biofuel production

ENRTF Funds Requested: $641,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Water (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.

The swine industry in Minnesota (ranks #2 in nation) generates 3.12 billion in economic activity. However, 9.3+ million hogs on over 3,225 farms generate a significant amount of wastewater, rich in nitrogen and phosphorus, which, if not properly managed, can contribute to water pollution and eutrophication of local watersheds. The current practices for swine manure management across the state store in the deep pit, and/or land application. During storage and direct land application, manure undergoes natural degradation leading to the emission of greenhouse gases (GHG). SM is the nation's second largest source of methane from livestock manure management. Traditional carbon capture technologies, such as direct-air carbon capture, require high energy inputs and significant water resources, making them costly and inefficient. Anaerobic digestion will capture methane and mitigate GHG emissions, used as heat and/or renewable energy production. Additionally, anaerobically digested manure will be used for microalgae production to remove excess nutrients available in manure. Unlike conventional crop-based biodiesel, algae don't compete with food production. Algae also capture 20 to 50 times more carbon than terrestrial plants while requiring less land and water. By integrating biological carbon capture, algae cultivation will contribute to circular bioeconomy development.

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

Our proposed solution will be the development of an integrated biological carbon capture via Anaerobic digestion and algae-based system to recover biofuel, bioenergy and nutrients from swine manure, reducing agricultural runoff while creating value-added products. This integrated system will utilize anaerobic digestion in combination with a microalgae cultivation setup to efficiently remove excess nitrogen and phosphorus from wastewater, mitigating its environmental impact. The cultivated algae biomass will be used for sustainable biofuel productions.
The project will focus on optimizing the anaerobic co-digestion process to maximize renewable methane production from the swine manure and agricultural residue. We will assess the feasibility of algae cultivation using treated wastewater, further utilizing remaining nutrients to improve water quality before discharge or reuse. We aim to refine system efficiency, evaluate scalability, and demonstrate the economic viability of this approach. By integrating this technology, livestock producers can reduce nutrient pollution, comply with environmental regulations, and explore new revenue streams. Funding will support system design, pilot implementation, and data analysis to validate the effectiveness of this approach. This research will provide a scalable and sustainable solution for managing swine wastewater, contributing to cleaner waterways and more resilient agricultural practices.

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 long-term goal of this effort is to protect the state's land and water resources, reduce carbon emissions, and create sustainable renewable biofuels, aligning with the public mission of environmental protection and resource conservation. By closing the loop on swine industrial wastewater and generating renewable energy, it sets the stage for broader adoption of eco-friendly, circular bioeconomy solutions at the farmers community. This project will provide a scalable, cost-effective solution for swine wastewater treatment while advancing renewable energy production at the farm level .

Activities and Milestones

Activity 1: Develop a novel anaerobic plug flow digester for co-digestion of swine manure and agricultural residue

Activity Budget: $265,579

Activity Description:
Swine manure will undergo solid-liquid separation, with the solid fraction combined with corn stover for mesophilic anaerobic digestion (AD), while the liquid fraction will be used for algae cultivation. We will assess biogas production potential through anaerobic co-digestion of swine manure and corn stover using an automated biochemical methane potential (BMP) system (AMPTS III, BioProcess Control) at mesophilic (38°C) and thermophilic (55°C) conditions. The study will determine the optimal total solid content by testing various mixing ratios. Microbial inoculum, sourced from the Riverview Dairy farm digester, will be pre-adapted to target temperatures.

A novel anaerobic digester will be designed and fabricated to facilitate dry anaerobic co-digestion, optimized by analyzing key parameters such as organic loading rate (OLR), solids retention time (SRT), and temperature to maximize methane yield and system stability. Hydraulic retention time (HRT) studies will be conducted to optimize gas production and organic degradation. To ensure system performance, operational parameters including pH, oxidation-reduction potential (ORP), volatile solids (VS), soluble chemical oxygen demand (SCOD), and volatile fatty acids (VFA) will be continuously monitored and analyzed.

Activity Milestones:

Description	Approximate Completion Date
Determine the biochemical methane potential of co-digested swine manure and lignocellulosic biomass	December 31, 2026
Develop a pilot-scale reactor to carryout continuous anaerobic co-digestion of swine manure and lignocellulosic biomass	March 31, 2027
Optimize the process parameters such as OLR, SRT and temperature to maximize biogas production	December 31, 2027

Activity 2: Developing an integrated algae-based system for excess nutrient recovery and agricultural runoff reduction from swine manure

Activity Budget: $237,655

Activity Description:
We will develop, design, and construct an integrated algal based facility for process testing and improvement. The liquid fraction of swine manure, obtained through solid-liquid separation before and after anaerobic digestion, will be utilized for integrated microalgae cultivation in continuous flow enclosed photobioreactor. This process will focus on cultivating high-starch and high-lipid microalgae, which serve as an ideal feedstock for sustainable biofuel production. We will screen and select microalgal strains capable of tolerating the high-nutrient conditions commonly found in Minnesota's water systems. Strains demonstrating efficient nitrogen, phosphorus, and organic matter removal, along with high starch and lipid accumulation, will be identified and characterized. Since lipid and starch biosynthesis share a common metabolic pathway in most microalgae species, we will induce targeted mutations through UV and chemical treatments to inactivate key enzymes involved in lipid and starch biosynthesis, thereby enhancing lipid and starch accumulation according to selected microalgal stains.

We will also develop culture strategies to optimize algal growth and biomass productivity, ensuring maximum nutrient uptake and efficient swine wastewater treatment. This work will contribute to a sustainable approach for managing swine wastewater while producing valuable bioproducts for energy and agricultural applications.

Activity Milestones:

Description	Approximate Completion Date
Identify the algae stains thriving in local municipal water	March 31, 2028
Evaluate the nutrient removal rate along with high starch or lipid content of algae	July 31, 2028
Develop and optimize culturing parameter conditions for the enhanced algal growth	October 31, 2028

Activity 3: Develop fermentation technology to convert algae into biofuel and conduct techno-economic analysis and and life-cycle assessment (LCA)

Activity Budget: $137,766

Activity Description:
We will investigate the fermentation process for convert cultured algal biomass into value-added biofuels and chemicals. Fermentation process parameters will be optimized to enhance the rate and yield of target products such as isobutanol, isobutyrate, etc. Algae with high starch or lipid content will be subjected to saccharification process by either using amylase, acid hydrolysis or engineered E. coli to break down complex carbohydrate into ferment sugars. These sugars will then be converted into biofuels through fermentation, with key process conditions such as sugar feeding rate, growth media composition, temperature, pH, and dissolved oxygen levels will be determined experimentally.

Based on the results obtained from activity 2 and milestone 1, a techno-economic analysis will be conducted to show the initial investment and estimated operational costs, and to provide the economic validation of the waste-to-algae process for value-added biofuels and chemicals. We will also conduct the LCA which will include assessment of environmental impacts of materials, chemicals, and energy inputs. The final results of the process will be compared with the conventional processes for isobutanol, isobutyrate or 1,4-butanediol production.

Activity Milestones:

Description	Approximate Completion Date
Development of algae into biofuel (isobutanol, isobutyrate, etc)	January 31, 2029
Develop a techno-economic model to assess the production cost	March 31, 2029
Develop a LCA model to evaluate the environmental impact of the whole process	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Luca Zullo	Agricultural Utilization Research Institute	Assist with the analysis and interpretation of data	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 work be funded?

The results will be implemented through pilot demonstrations, industry collaborations, and knowledge dissemination via publication and workshops at West central research and Outreach center, Morris. Swine producers will be engaged to adopt the system, supported by technical guidelines and economic feasibility assessments.

Ongoing efforts will seek funding through federal and state grants, industry partnerships, and private investments. Future research will focus on system optimization and commercialization. Additional work will be pursued through competitive grants (e.g., USDA, NSF), corporate sponsorships, and collaborations with agricultural innovation centers to ensure long-term sustainability and impact.

Project Manager and Organization Qualifications

Project Manager Name: Veluchamy Chitraichamy

Job Title: Research Assistant Professor

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

Dr. Veluchamy Chitraichamy is a Research Assistant Professor in the College of Food, Agricultural and Natural Resources Science at the University of Minnesota. Dr. Chitraichamy finished his post-doctoral training at the University of Guelph Canada on various research project that focus on biomass valorization, waste management, resource recovery, and environmental sustainability. Prior to he completed a PhD in Civil Engineering specialized in Environmental engineering at the Indian Institute of Technology Guwahati, India and earned B.Tech degree in Agricultural Engineering from Tamil Nadu Agricultural University, India. He has 9 years of research experience in sustainable waste management and resource recovery from various bioresource waste materials for biofuels and bioenergy production. His interdisciplinary research program focuses on integration of renewable bioenergy with agriculture and the environment. He has successfully conducted interdisciplinary research projects by collaborating with various academic institutions, industry stakeholders, and government agencies. Dr. Chitraichamy has guided students in laboratory research, experimental design, data analysis, fostering a collaborative and productive research environment that ensures rigorous project oversight and effective knowledge transfer to team members and stakeholders. His current and past research projects include the conversion of organic wastes into biofuel and value-added byproduct development, bioreactor designs, development of kinetic model and evaluating techno-economic analysis (TEA), evaluating novel farm-scale technologies, determining the fate of various contaminant and pathogens, monitoring greenhouse gas emissions and developing decision support guidance. He has a proven track record of publishing peer-reviewed journals, presenting research findings at national and international conferences. He advocates dissemination of science to the public through research outreach and extension activities, public talk and social media.

Organization: U of MN - WCROC

Organization Description:

In the College of Food, Agricultural and Natural Resources Sciences (CFANS) at the University of Minnesota, we look at

the bigger picture. When we envision a better tomorrow, it includes disease- resistant crops, products that protect our health, lakes free from invasive species, and so much more. We use science to find answers to Minnesota and the world's grand challenges and solve tomorrow's problems.

The Department of Bioproducts and Biosystems Engineering (BBE), in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

The UMN West central Research and Outreach Center (WCROC), located at Morris, will serve as the primary project location. The WCROC is a 1,100-acre, one of the University's living laboratories where agricultural research can be demonstrated at scale, and it serves as a regional center for agricultural stakeholders to discuss current issues in agriculture. The faculty and staff have considerable experience in developing and effectively implementing applied research, outreach, and extension programs at the applied farm-level.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
1 Assistant Professor		Principal Investigator, coordinate the research efforts, design experiments, mentor the graduate research assistant, write project reports			36.6%	0.24		$43,855
Researcher		Scientific staff, working on experiment design and data collection, manuscript preparation			25.9%	2		$165,417
2 Graduate Research Assistant (stipend and tuition fee)		Conducting the experiments, data collection, validation of results as proposed			83.6%	3		$359,004
							Sub Total	**$568,276**
Contracts and Services								
tbd	Service Contract	Sample analysis (10-15 samples each year) by an external testing laboratory (about $400-500 per sample) to determine the metagenomic 16S rRNA on the pilot scale digestor				-		$10,000
							Sub Total	**$10,000**
Equipment, Tools, and Supplies								
	Equipment	A pilot scale anaerobic digestor for enhanced methane production and algal photobioreactor will be built in the second year. The components includes, reactor, gas measuring devises, pumps, air compressor, insulation etc	This pilot scale reactor will enable us to test our proposed process in the real swine farm					$25,000
	Tools and Supplies	Chemicals, analysis kit, and personal protection supplies	Theses chemicals and tools are needed to carry out the proposed experimental work.					$25,454
							Sub Total	**$50,454**
Capital Expenditures								

							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	One conference trip per year for PI and 2 student per year, $250 registration per person ($750 total per year), 500 miles per year ($300), lodging for 3 persons and 2 nights ($900), and meals ($620 for 3 persons, two days per year)	PI and two students each year will present and share research results in in-state conferences, and network with peers.					$6,270
							Sub Total	**$6,270**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Open-access journal publication cost	Publish research results in open-access journal, about $2,000 per year for one paper					$6,000
							Sub Total	**$6,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$641,000**

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	**-**

Total Project Cost: $641,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: aef25940-a53.pdf

Alternate Text for Visual Component

An overview of the hypothesis/methodology and the project deliverable...

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Letter of Authorization to Submit	57c04a60-6cc.pdf
Audit	bdc4956b-d3a.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

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

No

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

N/A

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

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Wendy Moylan and University of Minnesota

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

Yes, I understand