



# Environment and Natural Resources Trust Fund

2027 Request for Proposal

## General Information

**Proposal ID:** 2027-070

**Proposal Title:** Dairy Wastewater to Clean Water: Sustainable Nutrient Recovery

## 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 project will develop and demonstrate a sustainable nutrient recovery system that will capture key nutrients from dairy wastewater and thereby reduce environmental risks including nutrient runoff and eutrophication problem.

**ENRTF Funds Requested:** \$498,000

**Proposed Project Completion:** June 30, 2030

**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.**

Minnesota's dairy industry contributes more than \$3.2 billion annually to the state's economy. However, 455,000+ dairy cows produce substantial volumes of wastewater that are rich in nutrients such as nitrogen and phosphorus, may pose significant environmental and operational challenges, including nutrient runoff contribute to algal blooms, water quality degradation, soil nutrient imbalances, odors affecting rural communities, and greenhouse gas (GHGs) emissions, particularly methane and nitrous oxide, if it is not properly treated. The current practices for dairy wastewater across the state have manure lagoons on their farms and land application. Nutrient removal, in particular nitrogen and phosphorus recovery, from dairy wastewater is a growing regulatory need. Anaerobic digestion will transform and/or hydrolysis the nutrients from organic to inorganic form, most of nitrogen and phosphorous are concentrated in the liquid effluent that could recovered through novel nutrient recovery technology, in addition to capturing methane and mitigate GHG emissions. We will develop an integrated sustainable nutrient recovery system that clean dairy wastewater instead of applying directly to the farm land or before it moves to nearby streams. This project will reduce the environmental impact of dairy wastewater nutrients entering streams aligned with Minnesota's nutrient reduction strategy.

### **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 circular nutrient recovery system that converts dairy wastewater into value added bioproducts fertilizer production, thereby reducing dairy manure based nutrient runoff and eutrophication. The developed system will capture and recover key nutrients such as nitrogen and phosphorus and recycle them back into agriculture. This project will reduce nutrient losses to surface and groundwater, decrease reliance on synthetic fertilizers, overall mitigate environmental risks. This project will benefit all size dairy operations ranging from 100 to 10,000 cows.

The project will focus on optimizing the anaerobic digestion process to transform nutrients (hydrolysis and dissolution) (from solid to liquid) from the dairy manure and captured the nutrients to produce clean water. We will assess the nutrient recovery techniques to improve water quality before discharge nearby waterbodies or reuse. By integrating nutrient recovery techniques, livestock producers can explore new revenue streams. Funding will support system design, reactor fabrication and operation, and data analysis to validate the effectiveness. This research will provide a scalable and sustainable solution for managing dairy wastewater, contributing to cleaner waterways and more resilient agricultural practices. This proposed solution aligns with climate-smart agriculture principles and Minnesota's nutrient reduction strategy.

### **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 recovery and reuse of nitrogen, phosphorus nutrients from wastewater streams can provide both economic and environmental benefits. Economically, the recovered bioproducts and bioenergy create a new value chain for rural stakeholders and reduce dependency on synthetic fertilizer and energy. Environmentally, reducing reliance on synthetic fertilizers lowers agriculture's carbon footprint, while capturing and reusing nutrients reduces the risk of water eutrophication and GHGs emissions.

The long-term goal of this effort is to protect the state's land and water resources, reduce carbon emissions, and create sustainable renewable bioproducts, aligning with the public mission of environmental protection and resource conservation.

## Activities and Milestones

### Activity 1: Development of a novel anaerobic digester for dairy wastewater nutrient hydrolysis and dissolution of organic nutrients into inorganic for recovery

**Activity Budget:** \$192,638

#### Activity Description:

We will focus on the design, development, and validation of an innovative anaerobic digestion reactor specifically engineered to enhance nutrient hydrolysis and dissolution in dairy wastewater. We will assess the nutrient dissolution and biogas production potential using an automated biochemical methane (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. We will develop a novel anaerobic digester configuration that improves the hydrolysis phase the rate-limiting step in conventional anaerobic digestion through optimized reactor design, enhanced mixing mechanisms, targeted microbial consortia, and controlled operational parameters (e.g., temperature, hydraulic retention time, and pH). The developed digester will promote efficient breakdown of complex organic compounds into soluble substrates, facilitating improved nutrient dissolution and subsequent bioconversion nutrient recovery and to biogas.

Process performance will be evaluated during anaerobic nutrient hydrolysis and/or dissolution and nutrient recovery based on nutrient solubilization rates, biogas production, chemical oxygen demand removal efficiency, and system stability (pH, electrical conductivity, alkalinity). This is a scalable technology that transforms dairy wastewater into a source of recoverable nutrients and energy, contributing to sustainable rural circular economy.

#### Activity Milestones:

Description	Approximate Completion Date
Determine the hydrolysis efficiency for proteins, fats, and carbohydrates found in dairy wastewater	December 31, 2027
Develop a pilot-scale novel reactor to improving nitrogen and phosphorus solubilization to enable downstream nutrient	April 30, 2028
Optimize the process parameters (OLR, SRT and temperature) to maximize nutrient dissolution and biogas production	November 30, 2028

### Activity 2: Design, fabricate and optimize an integrated nutrient recovery reactor to enhance phosphorus and ammonium capture from digested dairy wastewater

**Activity Budget:** \$203,263

#### Activity Description:

We will design, fabricate and optimize an integrated nutrient recovery reactor aimed at enhancing the capture and recovery of phosphorus and ammonium from digested dairy wastewater. The developed system will promote controlled precipitation (e.g., struvite formation) and improve nutrient capture efficiency through optimization of operational parameters such as pH, hydraulic retention time, mixing intensity, and chemical dosing. We will recover phosphorus and ammonia from digestate as slow release fertilizer (magnesium ammonium phosphate fertilizer) while minimizing reactor fouling and uncontrolled scaling. The optimization of struvite precipitation will involve both lab-scale batch and continuous experiments to determine the key reactor parameters. We will conduct batch studies at different chemical reagents to enhance nutrient recovery from digestate. Magnesium, ferric and calcium salts will be tested for their ability to recover phosphorus and ammonia through precipitation. pH will be maintained at 7.0 - 8.0 using aeration-induced CO<sub>2</sub> stripping. Mixing and air-to-solids (A/S) ratios (5–25) will be varied. Reaction parameters such as pH, temperature, orthophosphate, ammonia, and solids will be monitored. Blending, mixing time, and settling duration will be

standardized across tests. Performance targets include  $\geq 90\%$  phosphate removal, measurable ammonium reduction, improved precipitate settleability.

**Activity Milestones:**

Description	Approximate Completion Date
Optimize struvite recovery under variable chemical regimes in batch reactor	March 31, 2029
Design, fabricate and operate a lab-scale struvite recovery reactor in semi-continuous operation	July 31, 2029
Operation of lab-scale struvite recovery reactor in continuous operation	November 30, 2029

**Activity 3: Conduct techno-economic analysis (TEA) and life-cycle assessment (LCA) for the integrated nutrient recovery system**

**Activity Budget:** \$102,099

**Activity Description:**

We will conduct a comprehensive techno economic analysis (TEA) and life cycle assessment (LCA) of the integrated sustainable nutrient recovery system developed for phosphorus and ammonium capture from dairy wastewater. We will evaluate the system’s economic feasibility, environmental performance, and overall sustainability of the integrated project and projected full-scale implementation levels. Based on the results obtained from activity 1 and 2, a TEA will be conducted to assess the initial investment and estimated operational costs, energy consumption, chemical inputs, maintenance requirements, and potential revenue streams from recovered nutrient products. Sensitivity analyses will be performed to identify key cost drivers and evaluate the economic viability under varying operational and market conditions.

We will also conduct the life cycle assessment which includes assessment of environmental impacts of materials sourcing, reactor construction, operation, chemical usage, energy consumption, nutrient recovery, and end-product utilization. The combined TEA and LCA results will provide an integrated sustainability assessment, identify trade-offs between economic and environmental performance, and support decision-making for process optimization, scale-up, and commercial implementation. The primary outcome of this activity is to provide an overview of a possible nutrient recovery strategies, its feasibility, and the key technical, economic, and policy factors that enable its development.

**Activity Milestones:**

Description	Approximate Completion Date
Develop a techno-economic model to assess the production cost	January 31, 2030
Develop a LCA model to evaluate the environmental impact of the whole process	April 30, 2030
Finalize both models using optimized parameters obtained from activity 1 and 2	June 30, 2030

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Brad Heins	UMN-WCROC	Collaborator - assist the research efforts, mentor the graduate research assistant	No

## Dissemination

**Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.**

The project team will implement a comprehensive dissemination and data-sharing strategy to ensure that project findings, data, products, and outcomes are accessible to stakeholders, researchers, policymakers, and the public while fully complying with ENRTF Acknowledgement Requirements and Guidelines. Findings on nutrient recovery performance, Nitrogen, phosphorus and potassium mass balance, and water quality improvements will be shared through peer-reviewed journal publications, conference presentations, technical reports, and stakeholder workshops targeting dairy producers, watershed managers, and conservation professionals. Annual and final reports will be submitted to ENRTF as required, and plain-language summaries, fact sheets, and webinars will be developed to reach non-technical audiences. All datasets including water quality monitoring data, nutrient analyses, and recovery efficiency results will be quality-controlled, documented with metadata, and made publicly available through a UMN supported repository, with any confidential farm-level information anonymized. Recovered nutrient products and related documentation may be shared for research and demonstration purposes where appropriate. All publications, presentations, outreach materials, and digital content will prominently acknowledge support from the Environment and Natural Resources Trust Fund using the required funding statement and official logo, ensuring full adherence to ENRTF acknowledgement policies.

## 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 at West Central Research and Outreach Center, Morris, and conduct field day, workshops and other outreach activities in collaboration with industry and dairy stakeholders. Dairy 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, Twin Cities. Dr. Chitraichamy finished his post-doctoral training at the University of Guelph Canada on various research project that focus on biomass valorization, waste management and resource recovery, and environmental sustainability. He earned PhD in Civil Engineering specialized in Environmental Engineering

at the Indian Institute of Technology Guwahati, India and B.Tech degree in Agricultural Engineering from Tamil Nadu Agricultural University, India. Dr. Chitraichamy has 9 years of research experience in sustainable waste management and resource recovery from various bioresource waste materials. 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
<b>Personnel</b>								
1 Research Assistant Professor, 9 month appointment, seeking summer salary		Principal Investigator, coordinate the research efforts, design experiments, mentor the postdoc researcher, graduate research assistant and undergraduate and write project reports			36.6%	0.3		\$45,401
Post Doc/Researcher		Scientific staff, working on experiment design, data collection and analysis, manuscript preparation, research dissemination, supervise graduate and undergraduate student.			26.1%	2		\$165,285
1 Graduate Research Assistant (stipend and tuition fee)		Conducting the experiments, data collection, validation of results as proposed, research dissemination, work with undergraduate student.			24.2%	3		\$188,327
Two undergraduate students (\$17.46 per hour, 10 hour per week, and 20 weeks each year; 3% increase in each year afterwards)		Receive research training and collect experimental data			0%	0.75		\$21,694
							<b>Sub Total</b>	<b>\$420,707</b>
<b>Contracts and Services</b>								
TBD	Service Contract	Perform additional nutrient and other analysis as required to assess technologies, analyze chemicals, and provide needed data not available with WCROC research team in-house analytical tools.				0		\$10,000

							<b>Sub Total</b>	<b>\$10,000</b>
<b>Equipment, Tools, and Supplies</b>								
	Equipment	A pilot scale integrated anaerobic digester and nutrient recovery reactor for enhanced nutrient dissolution and methane production will be built in the second year. The components include two stage integrated reactors (\$14,000), gas measuring devices (\$5,000), pumps(\$1500), air compressor (\$1500), insulation (\$500), gas safety valves, regulator and pressure sensors (\$2500).	This pilot scale integrated reactor will enable us to test our proposed process in the real dairy farm					\$25,000
	Tools and Supplies	Funds (\$10,000 in Year 1, \$10,000 in Year 2, and \$10,023 in Year 3) are requested for experimental chemicals supplies, pumps, and PPE. Analytical supplies for conducting digestion and nutrient analysis of replicated digestate samples. Chemicals, analysis kits and personal protection supplies such as gloves masks, etc. Purchase of small, non-capital lab equipment supplies to enable research (transfer pump (\$3000) for loading and unloading materials).	These chemicals and analytical supplies are need to carryout the proposed experimental work.					\$30,023
							<b>Sub Total</b>	<b>\$55,023</b>
<b>Capital Equipment</b>								
							<b>Sub Total</b>	-
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
	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 graduate student each year will present and share research results in in-state conferences, and network with peers.					\$6,270
							<b>Sub Total</b>	<b>\$6,270</b>

<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	-
<b>Printing and Publication</b>								
	Publication	Open-access journal publication cost	Publish research results in open-access journal, about \$2,000 per year for one paper					\$6,000
							<b>Sub Total</b>	<b>\$6,000</b>
<b>Other Expenses</b>								
							<b>Sub Total</b>	-
							<b>Grand Total</b>	<b>\$498,000</b>

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	-

**Total Project Cost: \$498,000**

**This amount accurately reflects total project cost?**

Yes

## Attachments

### Required Attachments

#### *Visual Component*

File: [0e815982-682.pdf](#)

#### *Alternate Text for Visual Component*

The graphic illustrates the transformation of dairy manure nutrients from the solid phase to the liquid phase during anaerobic digestion and nutrient recovery processes. It further presents strategies for recovering nutrients from the liquid phase to convert dairy manure wastewater into clean water, thereby minimizing nutrient runoff and reducing eutrophication....

### Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	<a href="#">87c361c4-acb.pdf</a>

## 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?**

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

**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, 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