Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-487

Proposal Title: Cascading Generation of Hydrochar to Restore Farmed Peatlands

Project Manager Information

Name: Christian Lenhart

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

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Project Basic Information

Project Summary: This project explores integrating hydrothermal carbonization (HTC) into dairy manure management to convert digestate into hydrochar, improving farmed peatland restoration, enhancing carbon sequestration, and promoting sustainable land management practices.

ENRTF Funds Requested: $610,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Land (F)

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?

In the Future

Narrative

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

Drained and farmed peatlands are significant sources of greenhouse gas (GHG) emissions due to peat decomposition, contributing to climate change and soil degradation. These lands are often used for agriculture or grazing but require innovative management strategies to restore their carbon sequestration capacity and overall soil health. Conventional soil amendments fail to restore the long-term stability of organic matter and maintain the productivity of these peatlands. Simultaneously, dairy farms produce large volumes of manure, which creates environmental concerns due to nutrient runoff and GHG emissions from manure storage. Anaerobic digestion (AD) has emerged as a solution by converting manure into biogas, but it generates digestate, which has high moisture content and nutrient levels. This makes its transportation and application inefficient and costly, while its residual organics continue to release GHGs. There is a need for scalable, efficient ways to repurpose digestate and mitigate emissions. Integrating hydrothermal carbonization (HTC) with existing AD systems presents an innovative solution. HTC can convert dairy manure digestate into hydrochar, a stable, carbon-rich material that improves soil structure and enhances carbon sequestration. This project aims to address these interconnected challenges by utilizing HTC to support farmed peatland restoration and sustainable manure management.

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.

This project proposes integrating hydrothermal carbonization (HTC) with existing anaerobic digestion (AD) and combined heat and power (CHP) systems on dairy farms to address the challenges of farmed peatland restoration and manure management. HTC will convert the digestate solids from dairy manure into hydrochar, a carbon-rich material that enhances soil properties and supports peatland restoration. By utilizing waste heat from CHP systems, the process improves energy efficiency and reduces fossil fuel reliance. Hydrochar's benefits include improved moisture retention, enhanced nutrient availability, and carbon stabilization, making it a promising amendment for degraded peatlands.

The project will focus on optimizing the HTC process to maximize hydrochar yield and quality. Lab-scale tests will identify the best conditions for hydrochar production, followed by greenhouse and mesocosm trials to assess its effects on peatland vegetation, soil health, and carbon sequestration. A techno-economic analysis (TEA) and life cycle assessment (LCA) will evaluate the economic viability and environmental benefits of this integrated system. These activities will provide data on the sustainability, scalability, and potential for widespread adoption of hydrochar in farmed peatland restoration, promoting circular bioeconomy practices, enhancing carbon sequestration, and reducing GHG emissions from agriculture.

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?

This project will enhance the state's natural resources by integrating hydrothermal carbonization (HTC) with dairy manure management to reduce greenhouse gas emissions and improve soil health in farmed peatlands. Hydrochar application will restore degraded peatlands, enhancing carbon sequestration and improving soil moisture retention, supporting vegetation recovery. The project will also promote sustainable manure management, reduce nutrient runoff, and mitigate climate change impacts. Additionally, it will provide scalable solutions for farmed peatland restoration, contributing to the conservation and preservation of the state's peatland ecosystems and advancing circular bioeconomy practices for long-term environmental benefits.

Activities and Milestones

Activity 1: Lab-Scale hydrochar production from dairy manure digestate and characterization

Activity Budget: $223,109

Activity Description:
A lab-scale HTC system will be established to treat the digestate derived from on-farm digesters treating dairy manure. Key factors such as temperature (180-260°C), residence time (30 min-4 hours), and feedstock composition will be systematically tested to determine their impact on hydrochar yield and quality. The carbon retention, nutrient content, and structural characteristics of the hydrochar generated from manure digestate will be quantified, ensuring its effectiveness as a farmed peatland amendment. The chemical and physical properties of the biochar generated (e.g., pH, bulk density, porosity, surface area, carbon stability, and mineral composition) will be thoroughly characterized. Additionally, the HTC process water will be assessed for organic and inorganic nutrient composition, pH stability, and potential reuse to support peatland vegetation growth. The overall energy efficiency will also be calculated to evaluate the feasibility of using waste heat from CHP units burning biogas generated from dairy manure digestion, thus ensuring a smooth system connection between the CHP unit and the HTC system. By systematically evaluating these parameters, the HTC process will further be optimized to ensure the effectiveness of hydrochar for restoration of farmed peatlands while maintaining efficient energy utilization and minimizing GHG emissions.

Activity Milestones:

Description	Approximate Completion Date
Complete lab setup of a hydrothermal carbonization system to treat dairy manure digestate	September 30, 2026
Comprehensive characterization of hydrochar derived from manure digestate	March 31, 2027
Optimization of HTC process parameters to maximize hydrochar yield and quality	June 30, 2027

Activity 2: Hydrochar application for peatland restoration in greenhouse and mesocosm experiments

Activity Budget: $193,292

Activity Description:
This activity will evaluate the potential of hydrochar as an effective amendment for drained and farmed peatland restoration and long-term carbon sequestration. A series of greenhouse and mesocosm experiments will be conducted to assess the impact of hydrochar application on peatland vegetation growth, soil moisture retention, and carbon stabilization. Mesocosm tests will simulate peatland conditions in a controlled environment to evaluate the interactions of hydrochar with soil, water, and plant species before large-scale field deployment. Different hydrochar application rates will be tested to determine the optimal conditions for enhancing peatland recovery. Soil and plant health indicators, including nutrient availability and pH balance, will be monitored over time. The role of hydrochar in mitigating peatland degradation, improving water retention, and enhancing plant establishment will be comprehensively examined. Additionally, the potential of hydrochar on reducing GHG emissions from peatlands will be investigated, supporting its role in the mitigation of climate change.

Activity Milestones:

Description	Approximate Completion Date
Greenhouse and mesocosm trials to assess effect of hydrochar on peatland vegetation growth and soil	June 30, 2028
Analysis of carbon sequestration in hydrochar and resulting GHG emission reduction in peatlands	June 30, 2028

Activity 3: Techno-economic and environmental assessment

Activity Budget: $193,599

Activity Description:

Activity 3 involves detailed techno-economic analysis (TEA) and life cycle assessment (LCA) to evaluate the economic viability and environmental benefits of integrating HTC with AD and CHP systems. The TEA will calculate capital and operational costs of establishing and running an AD-HTC-CHP system within a dairy farm, revenue potential from hydrochar applications in farmed peatland restoration, and return on investment under different farm-scale scenarios. Cost-benefit analyses comparing HTC-integrated systems with conventional farmed peatland restoration practices will be included, and economic barriers will also be analyzed. Sensitivity analyses will be performed to assess market conditions, policy incentives, and carbon credit opportunities. The LCA will quantify GHG reductions, energy gains, carbon sequestration potential, and broader environmental impacts. This analysis will account for emissions at each stage of the process, from manure collection to hydrochar application in farmed peatlands. Energy balance studies will track waste heat utilization and efficiency improvements. The TEA and LCA results combined will provide data-driven insights to stakeholders on the sustainability and feasibility of HTC adoption for farmed peatland restoration. Ultimately, Activity 3 will establish a comprehensive framework for integrating HTC into dairy manure management and farmed peatland restoration while advancing decarbonization and circular bioeconomy.

Activity Milestones:

Description	Approximate Completion Date
Techno-economic analysis of hydrochar production and viability for farmed peatland restoration	March 31, 2029
Energy balance and GHG emissions reduction assessment through life cycle assessment	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Bo Hu	Department of BBE, University of Minnesota	Advising professor and co-principal investigator. Bo Hu will lead the aspects related to hydrochar.	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 work be funded?

The project's results will be implemented through partnerships with dairy farms, peatland restoration initiatives, and agricultural stakeholders, facilitating pilot-scale validation and scaling of the AD-HTC-CHP system. Findings will be disseminated via scientific publications, conferences, and outreach programs. Future funding will be sought through USDA, EPA, and industry collaborations, along with potential carbon credit programs to support large-scale hydrochar application. These efforts will drive the adoption of sustainable practices in farmed peatland restoration and manure management. Ongoing funding will be explored to continue expanding the technology and ensuring long-term environmental and economic benefits.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Phytoremediation for Extracting Deicing Salt	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 08g	$451,000
Quantifying Environmental Benefits of Peatland Restoration in Minnesota	M.L. 2023, , Chp. 60, Art. 2, Sec. 2, Subd. 08l	$754,000
Novel Nutrient Recovery Process from Wastewater Treatment Plants	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 04g	$486,000

Project Manager and Organization Qualifications

Project Manager Name: Christian Lenhart

Job Title: Research Associate Professor

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

Dr. Lenhart co-authored several widely-used management guides including the Aquatic Organism Passage Handbook for MnDOT (2019) and the Agricultural BMP Handbook for Minnesota (2017) for the Minnesota Department of Agriculture. He has led assessment and design of stream and wetland restoration projects and contributes to hydrologic and water quality monitoring efforts for The Nature Conservancy MN, ND, SD chapter. Chris has coordinated the professional restoration certification program for the Society of Ecological Restoration International and serves as president of the SER-Midwest-Great Lakes Chapter. He currently lives with his family in Roseville, Minnesota near Lake McCarrons. Originally from Defiance, Ohio, he has been involved with restoration, management and research related to wetlands and water quality in that region.

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

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. Almost 93 percent of students who earn CFANS undergraduate degrees find jobs in their
career field or enter graduate school within six months of graduation.

The Department of Bioproducts and Biosystems Engineering, 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.

We have a public impact through community engagement and extension efforts. We develop and deliver high quality, regionally and nationally-recognized research-based programs to meet current and emerging needs of industry and communities. We also have a long-standing tradition of close partnerships with alumni, industry professionals, organizations, government agencies, donors and community members.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Lead PI		Direct all research and personnel			36.6%	0.6		$97,056
Co-PI - summer salary only		Hydrochar production and techno-economic analysis			36.6%	0.12		$29,134
Professional Researcher		Lead lab work			36.6%	2.25		$218,658
Graduate student		conduct experiments. education			83.6%	3		$179,501
Multiple undergraduate students		experiment set up, assist graduate student			0%	0.69		$24,682
							Sub Total	**$549,031**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab and field supplies: chemicals, collection supplies, gloves, eyewear	to accurate and safely conduct proposed research					$29,490
							Sub Total	**$29,490**
Capital Expenditures								
		Upgrade the gas chromatography (GC)	Current GC can measure all the greenhouse gas but N2O. With this upgrade, the GC will be capable of measuring N2O.	X				$26,446
							Sub Total	**$26,446**
Acquisitions and Stewardship								

							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	tbd	$1500 for trips to gather peat, $1530 for trips to gather waste samples					$3,033
	Conference Registration Miles/ Meals/ Lodging	Two local trips to regional peatland restoration conferences in Minnesota	disseminate results and learn from peers					$2,000
							Sub Total	**$5,033**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$610,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		Upgrade the gas chromatography (GC)	required for proposed research **Additional Explanation :** N2O is a potent greenhouse gas and it is primarily released from soil and manure during microbial processes in the context of farmed peatland restoration and manure management. Monitoring N2O emissions is crucial to assess the effectiveness of hydrochar application in mitigating GHG emissions from peatlands. Currently UMN does not have accurate measurement of N2O and having this capability will provide vital data for optimizing agricultural practices, evaluating the environmental impact of the restoration process, and ensuring the project contributes to long-term climate change mitigation.

Non ENRTF Funds

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

Total Project Cost: $610,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 78f2a2ad-2d8.pdf

Alternate Text for Visual Component

This visual component shows the process flowchart for the integration of hydrothermal carbonization (HTC) with anaerobic digestion (AD) and combined heat and power (CHP) systems for farmed peatland restoration...

Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	c49854f8-a66.pdf
Audit	ab0681eb-06e.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, Bo Hu and Lingkan Ding at the 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

N/A