Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-143

Proposal Title: Cascading Hydrochar Production to Restore Farmed Peat Soils

Project Manager Information

Name: Bo Hu

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

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Project Basic Information

Project Summary: This project proposes using hydrothermal carbonization of digestate from organic waste treatment to produce hydrochar for farmed peatland restoration, enhance carbon sequestration, destroy emerging contaminants, and promote sustainable land management.

ENRTF Funds Requested: $536,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Land (F)

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.

Minnesota contains one of the largest peatland regions in United States, with peat soils covering about 10-14% of the state land. These peatlands are ecologically important because they store large amounts of carbon, regulate water, and provide critical wildlife habitat. However, a significant portion, especially in central and southern MN, has been drained and converted to agriculture, creating farmed peatlands, and therefore, contributing to carbon emissions due to peat decomposition and soil degradation. These lands are often used for crop production or grazing, and require innovative management strategies to restore their carbon sequestration capacity and maintain overall soil health. Conventional soil amendments fail to restore the long-term stability of organic matter and maintain the productivity of these peatlands. Meanwhile, Minnesota generates vast quantities of organic residuals, specifically digestate from anaerobic digestion (AD) facilities treating manure, food waste, and municipal solids. While AD recovers biogas combusted to generate electricity, the heat is often dissipated, and the digestate is high in moisture, nutrients, and potential contaminants like pathogen and PFAS. Land application of digestate possesses risks of nutrient runoff into lakes and rivers and continuous release of GHG. There is a need for scalable, efficient ways to repurpose digestate and mitigate emissions.

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 aims to address these interconnected challenges by utilizing HTC to support farmed peatland restoration and sustainable organic waste management. We propose integrating hydrothermal carbonization (HTC) with existing anaerobic digestion (AD) and combined heat and power (CHP) systems. HTC will utilize the heat from the biogas electricity generation and convert the digestate solids from various organic wastes into hydrochar. Hydrochar can mimic natural peat as it has a porous, carbon-rich structure similar to natural peat and the porosity helps retain water and nutrients in soils. Hydrochar can improve soil water-holding capacity, aeration, and microbial habitat, supporting plant growth in degraded or drained peatlands. Applying hydrochar to farmed peatlands can help replace lost organic matter and partially offset carbon loss from drained soils. Hydrochar has a slightly acidic pH and humic-like compounds, further mimicking peat's chemical environment for plants and microbes. Land application of these hydrochar will enhance soil properties and supports peat soil restoration. By utilizing waste heat from CHP systems, the process improves energy efficiency. The HTC can also synergistically break down or stabilize some possible emerging contaminants like PFAS. This project will combine lab-scale experiments to produce hydrochar, and greenhouse and mesocosm trials for peatland restoration.

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 organic waste 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 organic waste management, reduce nutrient runoff, destruct emerging contaminants, 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 various digestate and characterization

Activity Budget: $192,617

Activity Description:
A comprehensive lab-scale hydrothermal carbonization (HTC) system will be established to systematically treat digestate sourced from regional anaerobic digesters processing municipal wastewater, food waste, and other organic residuals. The primary objective is to define the optimal HTC process conditions by testing a matrix of temperatures (180-260°C) and residence times (30 min-6 hours) for difference digestate sources. Co-processing of different digestate feedstocks will also be conducted to evaluate the impacts on hydrochar yields and properties. The resulting hydrochar will undergo rigorous physiochemical characterization, including elemental composition, surface area, porosity, and pH, to ensure its compatibility with peatland ecosystems. Meanwhile, the fate of contaminants of emerging concern will also be tracked. Advanced mass spectrometry will be employed to measure the degradation of PFAS compounds, aiming to validate the potential for PFAS destruction in subcritical water environments. Additionally, the heavy metals will be analyzed using ICP-OES to assess if those metals are locked into non-bioavailable solid fractions. Finally, the liquid byproduct (i.e., process water) will be sampled for nutrient content (nitrogen, phosphorus, and potassium) measurements to evaluate its suitability for nutrient recovery as a liquid biofertilizer or recirculation back into the anaerobic digestion system to improve overall energy yields.

Activity Milestones:

Description	Approximate Completion Date
Complete lab setup of an HTC system and acquisition of diverse digestate feedstocks	September 30, 2027
Complete experimental HTC runs and physiochemical characterization of hydrochar	March 31, 2028
Complete contaminant fate analysis (PFAS/heavy metals) and process optimization	June 30, 2028

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

Activity Budget: $172,651

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. We will collaborate with Great River Greening, a non-profit specializing in ecological restoration and urban and rural habitat enhancement. They will serve as consultants, joining quarterly meetings to provide guidance on experimental design, monitoring strategies, data interpretation, and recommendations for scaling greenhouse findings to real-world restoration efforts.

Activity Milestones:

Description	Approximate Completion Date

Greenhouse and mesocosm trials to assess effect of hydrochar on peatland vegetation growth and soil	June 30, 2029
Analysis of carbon sequestration in hydrochar and resulting GHG emission reduction in peatlands	June 30, 2029
Advisory meetings with Great River Greening on greenhouse and mesocosm study	June 30, 2029

Activity 3: Techno-economic and environmental assessment

Activity Budget: $170,732

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 an industrial anaerobic digester, 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 digestate 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 organic waste 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, 2030
Energy balance and GHG emissions reduction assessment through life cycle assessment	June 30, 2030
Advisory meetings with Great River Greening on future field implementation strategy	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Chris Lenhart	University of Minnesota	Co-PI. Dr. Lenhart has been working on several research projects related to peatland restoration and he will help the group to design experiments on the ecological restoration of peat soil	Yes

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 research results will be submitted for publication in peer-reviewed journals. Our team will engage with Great River Greening and other possible local industry partners about potential applications of this technology. We intend to present the results as they are compiled via LCCMR reporting, publishing in scientific and engineering journals and conference presentations. The research team will prioritize dissemination at conferences in Minnesota. ENRTF will be acknowledged through use of the trust fund logo or attribution language on project print and electronic media, publications, signage, and other communications per the ENRTF Acknowledgment Guidelines.

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 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
Phytoremediation of PFAS from Soil	M.L. 2025, First Special Session, Chp. 1, Art. 2, Sec. 2, Subd. 08h	$1,066,000

Project Manager and Organization Qualifications

Project Manager Name: Bo Hu

Job Title: Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Bo Hu is a Professor and Director of Undergraduate Studies in the Department of Bioproducts and Biosystems Engineering at the University of Minnesota, where he has played a pivotal role in enhancing undergraduate education,

particularly in the area of sustainability. With his innovative teaching methods, Dr. Hu integrates sustainability concepts across various courses, providing students with both theoretical knowledge and practical, real-world applications. His focus on critical thinking and hands-on learning ensures that students are well-prepared to address global environmental challenges in their future careers.

In addition to his commitment to education, Dr. Hu has over 20 years of active research experience, specializing in biomass utilization, fermentative conversion, and phytoremediation. His research projects include innovative solutions for removing phosphorus from manure and wastewater, using plants to clean polluted soil and water, and exploring synthetic ecology through the co-cultivation of microalgae and fungi in lichen biofilms. His team is also working on upcycling low-quality agricultural byproducts into nutritious animal feeds.

Dr. Hu's research team at the University of Minnesota has developed cutting-edge techniques, such as 16s rDNA-based microbial analysis using high-throughput pyrosequencing to study microbial species in waste treatment, and ITS sequencing to identify fungal species. Additionally, his team is advancing several conversion platforms, including fungal and microalgae co-cultivation, pelletized fungal fermentation, and solid-state fermentation of filamentous fungi, to produce biofuels and bioproducts from agricultural waste while addressing nutrient removal and pollution in contaminated water.

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								
research faculty Hu/9 month appointment seeking summer salary		Lead Investigator/ oversee all lab components and personnel			26.8%	0.3		$74,648
contract research faculty Lenhart/appointment dependent on project funds		Co-PI overseeing all field components including data collection and personnel			26.8%	0.3		$49,984
professional researcher - appointment dependent on project funds		conducting experiments, assisting both PI's			26.8%	3		$320,879
							Sub Total	**$445,511**
Contracts and Services								
U of M lab services	Internal services or fees (uncommon)	analysis that cannot be done in Hu's lab				-		$9,273
							Sub Total	**$9,273**
Equipment, Tools, and Supplies								
	Tools and Supplies	Standard laboratory chemicals including acids and bases (e.g., hydrochloric acid and sodium hydroxide) will be used for pH adjustment, washing, and sample preparation. Reagents for elemental and nutrient analyses (e.g., nitrogen, phosphorus, and potassium standards) will be used to characterize hydrochar composition and assess its potential agronomic benefits. Additional chemicals will support soil and hydrochar characterization, including reagents	Standard lab chemicals are used to study the hdyrochar production in the lab anerobic digesters, and their physic-chemical properties. Some supplies are used for the field applications.					$40,134

		for organic carbon analysis, cation exchange capacity determination, and nutrient extraction. Materials for moisture determination, ash analysis, and carbon stability tests will also be required. Supplies will include filtration materials, centrifuge tubes, reaction vessels, glassware, sample containers, and personal protective equipment. Field supplies will include soil sampling bags, storage containers, plot markers, and application tools etc.						
							Sub Total	**$40,134**
Capital Equipment								
		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	mileage and per diem depending on location, sometimes 1 person, sometimes 2	$1500 for trips to gather peat and to gather waste samples					$1,500
	Conference Registration Miles/ Meals/ Lodging	Two local trips to regional peatland restoration conferences in Minnesota	disseminate results and learn from peers					$3,136
							Sub Total	**$4,636**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								

		Participant stipends (2 years/4 meetings per year/2-4 people per meeting)	Great River Greening will be joining our quarterly research group meeting starting in year 2 to provide feedback and suggestions on how to design experiments and how to implement this technology on the real-world applications. Great River Greening will have their staff members on both biochar production and field application present on the meetings.					$10,000
							Sub Total	**$10,000**
							Grand Total	**$536,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Equipment		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: $536,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: fbc620ea-982.docx

Alternate Text for Visual Component

Process to produce hydrochar and how hydrochar can be used to mimic peat for peat soil restoration...

Supplemental Attachments

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

Title	File
Authorization to submit	6d080ec2-67b.pdf
Supporting letter from Great River Greening	ec69d7b0-3cc.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, Finance Professional, 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