Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-418

Proposal Title: Sustainable Landfill Management for Waste Valorization and Recovery

Project Manager Information

Name: Juer Liu

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

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Project Basic Information

Project Summary: This project pilots sustainable landfill management at Bridgewater Landfill, optimizing gas recovery, treating leachate for PFAS/microplastics, and converting waste into resources, supporting long-term land conservation and circular waste management.

ENRTF Funds Requested: $890,000

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?

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 generated 6.34 million tons of municipal solid waste (MSW) in 2023, reflecting a 3.3% increase annually, with the majority ending up in landfills. Landfilling MSW typically consist of approximately 69.5% biomass materials, 15% petrochemical components, and various inorganic materials. The organic fraction possesses a thermodynamic heat of about ~960MJ per kmol, enabling anaerobic biodegradation to produce landfill gas (LFG) containing approximately 50% of methane, a potent greenhouse gas contributing to climate change. Improper landfill management leads to land degradation, contamination of soil and water, and habitat disruption. Key concerns include methane emissions, per- and polyfluoroalkyl substances (PFAS) and microplastic contamination in leachate, and inefficient resource recovery, which pose risks to surrounding ecosystems and groundwater. Current landfill practices fail to prevent long-term soil contamination and groundwater pollution, leading to increased land-use pressures as existing landfills reach capacity. Meanwhile, landfill fires, increasing operational costs, and contamination risks necessitate a sustainable waste-to-value strategy that integrates land preservation with pollution mitigation.

This project proposes a sustainable landfill management approach that enhances LFG utilization, remediates contaminated leachate, and converts waste into valuable byproducts. By implementing this strategy across Minnesota's 35+ landfill sites will contribute to long-term land conservation and environmental resilience.

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 focuses on sustainable landfill management to prevent land degradation, enhance resource recovery, and reduce the environmental footprint of landfills. The approach includes:

1) Optimizing landfill gas (LFG) recovery to minimize methane emissions and improve waste decomposition, reducing landfill expansion pressures. AI-driven algorithms will predict and enhance LFG yields, increasing renewable energy while mitigating soil and groundwater impacts.
2) Advanced leachate treatment to remove PFAS and microplastics, preventing contamination of surrounding wetlands, forests, and water bodies. A combination of nanobubble technology, biochar filtration, and microalgal remediation will allow for safer leachate recirculation, reducing environmental risks.
3) Catalytic pyrolysis for waste conversion will thermally treat contaminated biomass and non-biodegradable waste, destroying pollutants while recovering valuable byproducts like biochar and syngas. These materials can be reused for land rehabilitation, reducing landfill dependence and improving soil quality.

The project will be piloted at Bridgewater Landfill and analyzed for environmental and economic viability, providing real-world validation and a scalable model for modern landfill management. By bridging scientific innovation with practical application, this initiative will help extend landfill lifespans, reduce contamination risks, and promote sustainable land use planning, supporting Minnesota's conservation priorities.

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 has the following outcomes: 1. Extend landfill lifespans, reducing the need for new landfill sites and preserving Minnesota's forests, wetlands, and agricultural land; 2. Protect soil and groundwater by treating leachate, removing PFAS and microplastics, and preventing contamination; 3. Reduce methane emissions through enhanced landfill gas recovery, minimizing land degradation; 4. Convert waste into valuable byproducts such as biochar, which can restore soil health and improve land resilience, and 5. Demonstrate a replicable landfill sustainability model that integrates waste reduction, land conservation, and environmental resilience, helping policymakers and landfill operators adopt more sustainable land management practices across Minnesota.

Activities and Milestones

Activity 1: Develop an AI model Incorporating Single/Hybrid Algorithms to Accurately Predict and Optimize Landfill Gas Production in Local Minnesota Landfills

Activity Budget: $210,000

Activity Description:
This activity aims to develop an artificial intelligence model incorporating single or hybrid algorithms to accurately predict and optimize landfill gas (LFG) based on the municipal solid waste (MSW) characteristics. The model will use MSW composition and characteristics (e.g., C/H/O/N/S content, ash, waste quality, and age) along with environmental factors (e.g., oxygen presence, temperature, moisture content) as input variables. The developed AI model will be benchmarked against the EPA's Landfill Gas Emission Model (LandGEM) and conventional first order decay models (e.g., Gompertz, Logistic). Additionally, the influence of key input variables will be analyzed to enhance predictive accuracy and provide actionable insights for LFG yield improvement.

Furthermore, landfill characteristics and environmental conditions will be optimized based on model predictions. Specifically, the composition and concentrations of degradable biomass will be adjusted to align with the suitable molecular composition $C_6H_{10}O_4$, while minimizing minor elements such as sulfur and nitrogen. Microbial biostimulation technologies, such as methanogen inoculation, will be employed to manipulate microbial communities and fine-tune landfill conditions. Crucial operational parameters, including temperature, pH, time, moisture content, and biodegradable organic content, will be optimized to maximize LFG production.

Activity Milestones:

Description	Approximate Completion Date
Development of predictive model for landfill gas production	November 30, 2026
Identify key parameters and their impacts on gas yield	December 31, 2026
Optimization of waste composition and landfill conditions for enhanced landfill gas yield	March 31, 2027

Activity 2: Pilot-Scale Landfill Gas Collection and Energy Recovery System Designed for Specific Landfill Site

Activity Budget: $200,000

Activity Description:
The effectiveness of LFG recovery and utilization is influenced by intrinsic landfill factors such as scale, size, and type, as well as the availability of advanced technologies. This project will collaborate with Bridgewater Landfill to develop and optimize a pilot-scale LFG collection system for treating and recovering LFG at flow rates of 10-150 cfm. The system will include gas extraction wells, strategically placed vertical and/or horizontal piping, and AI-driven IoT and sensor networks to maximize the recovery of high-energy LFG. Advanced treatment technologies will be integrated to remove impurities, such as moisture, CO_2, O_2, VOCs, and heavy hydrocarbons, thereby enhancing methane concentration to meet different energy application requirements.

Furthermore, this activity will assess different LFG utilization strategies based on site-specific characteristics and gas flow rates. These pathways may include direct combustion for heating, electricity generation via turbines or engines, and the production of compressed/renewable natural gas. A comprehensive financial feasibility assessment will be conducted using LFG modeling (e.g., LFGcost-Web) to compare these options. Based on the findings, the pilot-scale energy recovery and conversion system tailored to the landfill's specific size and gas flow rate will be established and operated for demonstration and cost estimation.

Activity Milestones:

Description	Approximate Completion Date
Establish a pilot-scale landfill gas collection system	June 30, 2027
Integrate advanced technologies for LFG purification	June 30, 2027
Financial feasibility assessment of LFG utilization strategies	September 30, 2027

Activity 3: Enhanced Treatment and Recirculation of Landfill Leachate Containing PFAS and Microplastics

Activity Budget: $160,000

Activity Description:
In this activity, we will employ electric-field nanobubble technology in combination with surface active foam fractionation, sonolysis, and conventional separation techniques, to effectively separate short-chain PFAS and nanoplastics from leachate. Additionally, functionalized biochars will be developed through functionalizing by renewable biopolymers rich in amino and hydroxyl groups. To further optimize treatment efficiency, Computational Molecular Dynamics simulation and Density Functional Theory calculations will be utilized to investigate PFAS/nanoplastics interactions at the air-water interface and their dynamics behavior across gas-liquid-solid phases. This approach will facilitate the effective adsorption of PFAS and nanoplastics from leachate, thereby reducing the burden on subsequent treatment processes.

Furthermore, pilot-scale airlift/bubble-column photoreactors (50 L ~ 2000 L) equipped with auxiliary components will be established for microalgal cultivation in leachate. This approach will enable simultaneous removal of PFAS and microplastics while converting nutrients into valuable microalgal biomass.

Lastly, we will implement advanced oxidation process, such as non-thermal plasma and/or catalytic concentrated high-intensity electric field technologies developed in our lab, to further degrade contaminants in leachate. The treated leachate will be recirculated into the landfill at an optimized leachate recirculation rate (<4.0 L/d/m3), maintaining the moisture content of 40 % ~60% to enhance LFG generation.

Activity Milestones:

Description	Approximate Completion Date
Development of electric-field nanobubble technology and functionalized biochar for leachate pretreatment	September 30, 2027
Optimization of pretreatment efficiency by using computational simulation and modeling	December 31, 2027
Establishment of pilot-scale microalgal cultivation and AOP process for leachate remediation	March 31, 2028

Activity 4: Catalytic Thermal Processes for Efficient Destruction of Pollutants in Microalgal Biomass and Solid Wastes Containing PFAS and Microplastics

Activity Budget: $200,000

Activity Description:
This activity focuses on the thermal conversion of microplastic- and PFAS-containing microalgal biomass, functionalized biochar, and non-biodegradable solid waste from MSW to mitigate contamination. The process will be first conducted using our developed lab-scale microwave-assisted pyrolytic system to break down persistent pollutants while generating valuable byproducts. To optimize key operating parameters, including temperature (400 - 900oC), loadings of catalysts

(e.g., ZSM-5 and CaO), heating rate, and reaction time, this activity will utilize Response Surface Methodology and Artificial Neural Network for precise modeling and optimization. These approaches will maximize the degradation of PFAS and microplastics while enhancing product yields. The resulting biochar will be either reused for leachate filtration or recirculated into landfill anaerobic digestion processes to enhance LFG production.

Additionally, pilot-scale pyrolysis of contaminated materials and wastes will be conducted under optimized conditions at a landfill site to assess technical feasibility and scalability. The fate, redistribution, and transformation of PFAS and microplastics during pyrolytic processing will be analyzed using LC-MS/MS to refine operational strategies. Moreover, syngas and bio-oil compositions will be evaluated, with a targeted syngas yields of CH4 (> 6 mol%), H2 (> 20 mol%), and CO (>40 mol%), to support potential commercial applications in sustainable energy recovery.

Activity Milestones:

Description	Approximate Completion Date
Optimization of key operating parameters in lab-scale pyrolysis system	March 31, 2028
Implementation of optimized conditions in pilot-scale pyrolysis system for contaminant destruction	September 30, 2028
Analysis of transformation pathways of PFAS and microplastics to refine operational strategies	December 31, 2028

Activity 5: Systematic Analysis of the Availability and Effectiveness of the Proposed Landfill Management

Activity Budget: $120,000

Activity Description:
This activity will evaluate the availability and effectiveness of the proposed landfill management by assessing key parameters, including techno-economic feasibility, environmental impacts, and social considerations. Data collected under varying process conditions and treatment durations will be analyzed and reprocessed to determine the applicability and scalability of this technology.

We will also provide quantitative insights for highlighting the advantages of this landfill management approach for waste-to-value development compared to conventional practices. To assess economic feasibility, we will employ the EPA's LFGcost-Web model alongside Techno-Economic analysis to estimate capital and operational costs of our proposed technology, which integrated LFG collection and valorization, microalgae-based leachate bioremediation, and catalytic pyrolytic processes for contaminant destruction. Additionally, Life Cycle Assessment and Environmental Impact Assessment will be conducted to quantify reduction in greenhouse gas emissions and organic wastes while also estimating potential revenue from energy recovery.

Additionally, we will refine and optimize the proposed landfill management framework by comparing different technological approaches against sustainability criteria. The findings will inform evidence-based recommendations and technical strategies aimed at maximizing long-term economic benefits and environmental sustainability. Ultimately, this work will provide critical insights and guidance to support future scaling and commercial implementation of advanced landfill management solutions in Minnesota.

Activity Milestones:

Description	Approximate Completion Date
Data collection and analysis	December 31, 2028
Systematic analysis to assess environmental, economic, and social impacts	January 31, 2029
Formulate technical strategies for scaling and commercial implementation	March 31, 2029
Final report on this project with publication of peer-reviewed papers	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Andi Sutton	Southeast Regional Sustainable Development Partnership, UMN Extension	Co-PI	No
Glen Castore	Bridgewater Township	Community Partner	No
Roger Ruan	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 work be funded?

The Bridgewater Landfill pilot will demonstrate how landfill management innovations can protect Minnesota's landscapes and extend landfill usability. UMN Southeast RSDP will engage stakeholders to encourage statewide adoption, with findings informing policy recommendations for sustainable landfill management. After a successful pilot, the model will be expanded to other landfills, integrating best practices for waste-to-value transformation, land rehabilitation, and pollution mitigation. Long-term funding will come from federal and state grants, industry partnerships, and revenue from recovered materials and renewable energy, promoting national interest and broader adoption of sustainable landfill management strategies.

Project Manager and Organization Qualifications

Project Manager Name: Juer Liu

Job Title: Research Professional 5

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

Dr. Juer Liu is a Researcher V and Associate Director at the Center for Biorefining, Department of Bioproducts and Biosystems Engineering, University of Minnesota. She holds a Ph.D. in Food Science with a minor in Bioproducts and Biosystems Science, Engineering, and Management. A seasoned project manager and researcher, Dr. Liu specializes in sustainable materials processing, waste valorization, and advanced recycling technologies. She leads innovative projects that transform agricultural and industrial waste into high-value products, with expertise in microwave-assisted depolymerization, high-pressure homogenization, and catalytic recycling, positioning her at the forefront of sustainable technology development. Dr. Liu has successfully managed large-scale research initiatives, securing funding from industry partners, government agencies like the USDA, DOE, and NSF, and organizations such as the Almond Board of California and LCCMR. Her ability to build strategic partnerships has been pivotal to her success. A notable example is her work on enhancing the antioxidant properties of almond hulls, demonstrating her leadership in resource recovery and circular economy applications. With 18 peer-reviewed journal articles, one book chapter, and over 620 citations, Dr. Liu's research has significantly contributed to food sustainability, biosecurity, and waste-to-value innovations. She has also taught courses like Renewable Energy Technologies and Food Process Engineering for eight semesters, underscoring her commitment to education and workforce development. Dr. Liu's leadership is further evidenced by multiple national and international awards, including the IFT Student Leadership Award and top research poster honors at major scientific conferences. An active member of IFT, AIChE, ACS, and RCS, she is dedicated to mentoring students and leading

interdisciplinary research teams. With extensive experience translating research into real-world applications, Dr. Liu is uniquely qualified to lead sustainability-focused initiatives, ensuring meaningful environmental and economic impact.

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 helps 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								
Lead PI - .9 FTE dependent on grant funding		direct all research and personnel			36.6%	0.9		$81,706
Post doc		manage and conduct lab experiments and analysis			25.9%	3		$251,866
Graduate Student		help Post Doc with experiments and analysis, education			83.6%	3		$179,501
Extension staff Regional Sustainable Development Partnerships - Rochester		outreach/partnership with Bridgewater Township (landfill site) and project management			36.6%	0.4		$55,150
Co-PI - summer salary only		lead specifc research			36.6%	0.15		$45,341
							Sub Total	**$613,564**
Contracts and Services								
tbd - lab services	Internal services or fees (uncommon)	analysis				-		$8,000
							Sub Total	**$8,000**
Equipment, Tools, and Supplies								
	Equipment	components	for lab testing system development and testing					$36,348
	Tools and Supplies	1. lab and field supplies to include biogas and leachate collection tools, microalgae feedstocks, chemicals reagents for in vitro simulate	for the safe and accurate collection of biogas and leachate, experiments, and outreach					$36,088

		fermentation, consumable supplies for analytical instruments 2. personnel protection such as gloves, protective eyewear 3. outreach materials						
							Sub Total	**$72,436**
Capital Expenditures								
		Components including mcirowave-assisted reactor vessel, insulation materials, magnetrons, control, motors, mixer, feeder, valves, etc.	for building pilot-scale demonstration system for pyrolysis	X				$190,000
							Sub Total	**$190,000**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	tbd	collect byproducts of landfill in Bridgewater Township, outreach					$6,000
							Sub Total	**$6,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$890,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		Components including mcirowave-assisted reactor vessel, insulation materials, magnetrons, control, motors, mixer, feeder, valves, etc.	necessary for the research proposed **Additional Explanation :** The capital equipment purchased with the appropriation will remain essential for advancing sustainable landfill management beyond the project's completion. The pilot-scale microwave-assisted pyrolysis system, including reactor vessels, control systems, magnetrons, motors, and feeders, will continue to support waste valorization research at the University of Minnesota. It will facilitate ongoing studies on landfill gas optimization, PFAS and microplastic degradation, and biochar production for land rehabilitation. Additionally, the equipment will be available for future grant-funded research, industry partnerships, and student training, ensuring long-term contributions to circular waste management and environmental sustainability in Minnesota.

Non ENRTF Funds

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

Total Project Cost: $890,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 9deb260b-c6e.pdf

Alternate Text for Visual Component

An integrated bioprocessing approach for sustainable landfill management: modeling and optimizing landfill gas recovery and energy utilization; multi-step leachate treatment using nanobubble technology, biochar filtration, and microalgae cultivation; and pilot-scale catalytic pyrolysis for PFAS/microplastics destruction and resource recovery. Feasibility for advancing a circular economy in Minnesota is assessed....

Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	c8c159f2-346.pdf
Support Letter from Bridgewater Township	6404c7e9-f71.jpe
Audit	3bf86e0f-1da.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?

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

N/A