Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-078

Proposal Title: Expanding Minnesota Plastic Recycling Beyond Mechanical Limits

Project Manager Information

Name: Roger Ruan

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

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Project Basic Information

Project Summary: This project tests whether targeted plastic recovery combining chemical recycling can measurably increase the recycling capacity of hard-to-recycle plastics and reduce landfill and incineration impacts in Minnesota.

ENRTF Funds Requested: $300,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Small Projects (G)
Secondary Category: Resiliency (A)

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?
During the Project and In the Future

Narrative

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

Plastic waste poses a significant challenge to Minnesota's efforts to meet long-term waste diversion and environmental resilience goals. The Minnesota Legislature has established a target for metropolitan counties to recycle 75% of total solid waste by 2030, yet current recycling rates remain well below this benchmark. Plastic waste represents one of the largest missed opportunities for diversion, with a capture rate of only 12.6% in the metropolitan area, the second lowest among material streams, despite contributing the largest share of greenhouse gas emissions due to their fossil-based origin and predominant disposal through landfilling or incineration.

This gap reflects not only behavioral or educational factors, but more fundamentally the structural limitations of exisiting recycling infrastructure. Current infrastructure is optimized for mechanical recycling of a narrow set of plastics—primarily PET, HDPE, and PP in clean, rigid forms—because these materials are easier to sort and have established markets. In contrast, hard-to-recycle plastics remain largely unaddressed. If even 20–30% of currently unrecovered plastic materials—such as flexible packaging and multi-layer films—could be captured and processed through alternative pathways, this could represent a meaningful increase in overall recycling rates and reduce a significant portion of plastic directed to disposal pathways.

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.

Chemical recycling processes can convert plastic waste into chemical building blocks that can be used to manufacture new plastic resins, enabling circular recycling of materials currently incompatible with mechanical recycling. Realizing this potential depends not only on advancing conversion technologies, but also on building the upstream infrastructure to identify, collect, sort, and pre-process currently hard-to-recycle plastics into suitable feedstocks, which is a critical missing link between existing recycling infrastructure and emerging chemical recycling pathways.

This project proposes an integrated, feasibility-focused approach to evaluate how target recovery strategies and chemical recycling technologies can be aligned to expand plastic recycling and quantify their potential contribution to Minnesota's 75% solid waste recycling goal by 2030. Working with UMN Como Recycling Facility, the project will identify and characterize plastic streams currently excluded from recycling programs and conduct pilot-scale sorting demonstrations to assess practicality and diversion potential. Two complementary chemical recycling pathways—microwave-assisted catalytic conversion of mixed polyolefin and microwave-assisted depolymerization of hard-to-recycle PET — will be evaluated. Rather than assuming large-scale deployment, results will define feasibility limits, decision thresholds, and conditions under which chemical recycling offers improved environmental benefits over current disposal pathways.

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 strengthen Minnesota's waste management resilience by generating practical data to increase plastic diversion and reduce plastic disposal impact. Outcomes include:
(1) identification and quantification of hard-to-recycle plastic streams with realistic diversion potential,
(2) demonstrated targeted collection and sorting strategies compatible with chemical recycling operations,
(3) performance data for chemical recycling pathways capable of handling hard-to-recycle plastics, and
(4) decision-support framework identifying conditions under which these approaches are environmentally and economically viable..
Together, these outcomes will enable state agencies and recycling operators to make informed decisions about how targeted recovery and chemical recycling can contribute to increased recycling

Activities and Milestones

Activity 1: Pilot Evaluation of Expanded Plastic Recovery Strategies for Chemical Recycling

Activity Budget: $67,766

Activity Description:
The UMN Como Recycling Facility will lead this activity in identifying, assessing, and demonstrating expanded plastic recovery strategies. The focus is on developing and evaluating practical strategies to collect, sort, and pre-process hard-to-recycle plastics into suitable feedstocks for chemical recycling.
The team will first identify campus locations and activities where hard-to-recycle plastics are routinely generated and discarded, including shipping and receiving, dining back-of-house operations, and housing move-out events. These efforts will produce a set of candidate plastic streams that are currently excluded from recycling programs. To estimate system-level impact, the project will conduct small-scale sampling and short-term collection trials to estimate annual tonnage and diversion potential.
Selected streams will then be evaluated through pilot-scale sorting and pre-processing demonstrations using manual methods and existing workflows, aided where appropriate by simple tools such as spot material identification checks. These trials will assess ease of identification, labor requirements, contamination risks, and compatibility with current recycling operations. The sorted materials will be aggregated to create representative pilot feedstocks for laboratory-scale chemical recycling trials at UMN. The process results will be evaluated for transferability to other Minnesota institutions such as hospitals, distribution centers, food processors, and other facilities with similar waste profiles.

Activity Milestones:

Description	Approximate Completion Date
Identify campus sources and candidate hard-to-recycle plastic streams.	December 31, 2027
Complete sampling and short-term collection trials to estimate diversion potential.	June 30, 2028
Conduct pilot-scale sorting and pre-processing feasibility demonstrations.	December 31, 2028
Prepare representative pilot feedstocks for laboratory-scale chemical recycling trials.	March 31, 2029
Complete feasibility and scalability assessment, including infrastructure requirements.	June 30, 2029

Activity 2: Development of Chemical Recycling Technologies for Hard-to-Recycle Plastics

Activity Budget: $179,402

Activity Description:
This activity will develop and evaluate chemical recycling technologies matched to the plastic streams identified and sorted in Activity 1, building on the project team's extensive prior work in microwave-assisted plastic conversion. For mixed polyolefin-rich plastics, including flexible packaging and multi-laminates, this work builds on previously developed continuous microwave-assisted catalytic pyrolysis (CMAP) systems that have demonstrated high energy efficiency, uniform heating using SiC-based microwave absorbers, and scalability toward multi-ton-per-day operation. In this project, efforts will focus on developing more stable catalysts and fine-tuning operating conditions at elevated temperatures to optimize production of light olefins suitable as chemical recycling feedstocks, while tolerating heterogeneous feedstock composition, additives, and organic contamination.
For hard-to-recycle PET streams, including contaminated PET and polyester-based textiles and fibers, the project will develop microwave-assisted depolymerization processes. Preliminary results indicate that microwave heating accelerates solvent diffusion and PET swelling, significantly reducing reaction time. Microwave-responsive heterogeneous catalysts will be evaluated to achieve high conversion and selectivity toward PET monomers while enabling catalyst recovery, tolerance to contaminants, and efficient monomer purification. Laboratory-scale experiments and small pilot demonstrations will generate feasibility and performance data to guide future scale-up.

Activity Milestones:

Description	Approximate Completion Date
Develop robust catalysts for high-temperature CMAP olefin production.	June 30, 2028
Optimize CMAP operating conditions using representative mixed polyolefin feedstocks.	December 31, 2028
Develop robust catalysts for microwave-assisted PET depolymerization	December 31, 2028
Optimize microwave-assisted depolymerization process for difficult-to-recycle PET	June 30, 2029
Conduct laboratory-scale demonstrations using selected feedstocks informed by Activity 1 results.	December 31, 2029

Activity 3: Techno-Economic and Systems Analysis for Integrated Plastic Recovery and Chemical Recycling

Activity Budget: $52,832

Activity Description:

This activity will evaluate the technical feasibility, economic performance, and system-level implications of integrating expanded plastic recovery strategies with chemical recycling technologies. Using data generated from Activities 1 and 2, the project team will develop process flow diagrams and mass and energy balances for representative recovery and conversion pathways. Analyses will include collection, sorting, pre-processing, chemical conversion, and product recovery steps to capture system-wide interactions and constraints. A key deliverable of this activity is a publicly accessible decision framework summarizing which plastic streams and recovery pathways warrant further consideration under Minnesota conditions.

The techno-economic analysis will estimate capital and operating costs, energy use, and material yields, as well as assess sensitivity to feedstock variability, scale, and operating conditions. A market assessment will evaluate potential end uses for recovered products, including chemical feedstocks and intermediates, and their compatibility with existing recycling and plastics manufacturing value chains. Scenario analyses will examine scalability from the UMN campus to larger institutional, regional, or statewide contexts, identifying infrastructure needs and practical limitations. The activity will produce decision-support guidance to inform future planning, investment, and policy discussions, without assuming full-scale implementation under this project.

Activity Milestones:

Description	Approximate Completion Date
Define system boundaries, assumptions, and performance metrics for integrated recovery and recycling pathways.	December 31, 2027
Develop process flow diagrams and mass/energy balances using laboratory-scale results.	June 30, 2028
Estimate capital and operating costs for recovery, pre-processing, and chemical recycling pathways.	December 31, 2028
Evaluate potential end-use markets and integration with existing recycling and plastics value chains.	June 30, 2029
Assess scalability from the UMN campus to regional and statewide implementation scenarios.	December 31, 2029
Finalize techno-economic analysis and decision-support guidance for future implementation.	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Natalie Hunt	University of Minnesota	Co-PI for Activity 3, leading techno-economic and systems analysis, supporting evaluation of project feasibility and salability.	Yes
Ahnika Seifert	Como Recycling Facility	Co-PI for Activity 1, coordinating pilot recovery efforts at the Como Recycling Facility, supporting identification and sorting of candidate plastic streams, facilitating data collection, and ensuring alignment between facility operations and project objectives.	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.
Project results will be disseminated through technical publications, public reports, presentations, and stakeholder engagement to ensure findings are accessible to entities that manage recycling and waste systems in Minnesota. Research outcomes, including data on plastic recovery strategies, chemical recycling performance, and techno-economic feasibility, will be documented in a final project report and shared with state and regional stakeholders such as the Minnesota Pollution Control Agency (MPCA), county solid waste offices, and recycling operators in the Twin Cities metropolitan area.

Findings will be presented through workshops or conferences such as the Resource Recycling Conference or regional recycling meetings. Targeted briefings will be conducted with MPCA, metropolitan counties, and major recycling operators to support direct application of findings in planning and policy decisions. through Results will also be submitted to peer-reviewed journals and presented at academic conferences to support broader knowledge transfer. The UMN Como Recycling Facility will assist in communicating operational insights to recycling practitioners.

All publications, presentations, and outreach materials will acknowledge the Minnesota Environment and Natural Resources Trust Fund in accordance with ENRTF acknowledgement requirements, including use of the ENRTF logo or attribution language where appropriate.

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 results will be used to guide planning and decision-making for expanding plastic recovery in Minnesota. Findings will be shared with MPCA, metropolitan county recycling coordinators, and facility operators to inform the feasibility and conditions for targeted recovery and chemical recycling options. Decision-support outputs will help determine whether and how expanded pilots or implementation studies are justified and can be carried out. Future work could be supported through competitive federal grants, state agency programs, additional LCCMR funding, or public–private partnerships.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Methods to Destroy PFAS in Landfill Leachates	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 04a	$200,000
Preventing PFAS and Microplastics Contaminants across Minnesota	M.L. 2024, , Chp. 83, Art. , Sec. 2, Subd. 08k	$656,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Roger Ruan is inducted as a Fellow of the National Academy of Engineering (NAE, Class 2025) and the National Academy of Inventors (NAI, Class 2023), and a Fellow of multiple other esteemed organizations, including ASABE, IFT, IAAM, and Vebleo. He has received numerous awards, including the International Bioprocessing Association's Pandey Award, the CAFS Professional Achievement Award, and the Scientist of IAAM Award. Dr. Ruan's research focuses on renewable energy and environmental technologies for sustainable development and the circular economy. His work spans biomass and solid waste pyrolysis and gasification, including plastic waste, to produce chemicals, materials, fuels, and energy. He has also developed novel wastewater treatment technologies using anaerobic digestion, microalgae cultivation, and hydroponics. Additionally, he specializes in pathogen disinfection and pollutant control using catalytic non-thermal plasma, low-temperature and pulse microwave, photocatalytic intensive pulse light, and NMR/MRI applications for nitrogen fixation, food safety, and food quality enhancement. Dr. Ruan has published over 600 peer-reviewed journal articles, authored two books and 30 book chapters, and holds 21 U.S. patents. He ranks 83rd nationally and 190th globally in Engineering and Technology according to research.com and holds the Number One global ranking in microwave pyrolysis and microalgae and wastewater treatment research per Web of Science. His work has an h-index of 105, an i10-index of 527, and over 43,000 citations on Google Scholar. He has secured over $45 million in research funding from agencies such as USDA, DOE, DOT, and DOD. As a project manager on several LCCMR-funded projects, his work has led to U.S. patents and technology licensing. His technical expertise and project management experience ensure the successful execution of proposed projects.

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								
Professor/faculty		PI - 9 month appointment (2 weeks summer salary) - oversee development of microwave-assisted catalytic processes, experimental design, catalyst development oversight, supervision of laboratory demonstration, and mentor postdoc and GRA.			36.6%	0.15		$37,533
Professor/faculty		Co-PI - contract faculty (funding dependent) - lead system modeling and techno-economic analysis integrating data, develop of process flow models, cost and energy analysis, scalability evaluation, and preparation of decision-support guidance relevant to Minnesota recycling systems.			36.6%	0.3		$26,746
Post Doc Researcher		Conduct the majority of experimental research for chemical recycling technologies, catalyst synthesis, operation of microwave-assisted reactors, reaction optimization, product characterization, and data generation supporting techno-economic modeling.			26.1%	1.5		$124,917
Graduate Research Assistant		Assist with feedstock preparation, catalyst testing, laboratory experiments, and data collection. The student will also support preparation of representative plastic feedstocks obtained through pilot recovery trials.			24.2%	0.75		$47,081
							Sub Total	**$236,277**
Contracts and Services								
Operational services at the UMN Como Recycling Facility for pilot recovery demonstrations	Internal services or fees (uncommon)	Recycling facility labor support for collection and sorting trials; Use of facility equipment and space for waste characterization; Handling and staging of plastic materials for feedstock preparation; and operational support for pilot recovery demonstrations				0		$8,266
							Sub Total	**$8,266**

Equipment, Tools, and Supplies								
	Equipment	Benchtop plastic shredder	Size reduction of collected plastic waste to prepare representative feedstocks.					$4,600
	Equipment	Plastic granulator and sizing attachments	Preparation of uniform plastic particles for chemical recycling experiments.					$4,400
	Equipment	Microwave reactor tubes, vessels, and fittings	Reactor hardware for microwave-assisted catalytic plastic conversion.					$4,800
	Equipment	SiC microwave absorbers and catalyst holders	Materials enabling efficient microwave heating and catalyst support.					$4,500
	Equipment	Gas flow controllers, probes, and sampling hardware	Monitoring and control of reaction gases during chemical recycling experiments.					$4,700
	Equipment	Feedstock preparation and measurement tools	Tools used to prepare, measure, and handle plastic feedstocks collected during pilot recovery trials.					$4,000
	Tools and Supplies	Catalyst precursor chemicals, depolymerization reagents and solvents, plastic feedstock sampling and preparation materials, analytical consumables (GC/GC-MS standards, vials, filters), and general laboratory consumables (glassware, tubing, seals, PPE)	Required for plastic conversion experiments and product characterization.					$28,457
							Sub Total	**$55,457**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								

							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$300,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

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

Total Project Cost: $300,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 538fab95-3dd.pdf

Alternate Text for Visual Component

The figure illustrates the limitations of current mechanical recycling and the opportunity to expand plastic circularity using microwave-assisted catalytic pyrolysis and depolymerization. These technologies convert hard-to-recycle mixed polyolefins and PET into chemical intermediates that can be used to manufacture new plastics....

Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	e0277ca5-5a3.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?

N/A

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, Department Finance and Riana Fletcher, Sponsored Projects Administration

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