Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-419

Proposal Title: Waste Textiles Chemical Recycling via Catalytic Microwave-Assisted Depolymerization

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 develops a catalytic microwave-assisted depolymerization process to efficiently convert waste textiles into reusable monomers, promoting sustainable, low-energy textile recycling and supporting circular economy principles.

ENRTF Funds Requested: $300,000

Proposed Project Completion: June 30, 2028

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?
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 faces a textile waste crisis, with over 85% of discarded textiles ending up in landfills or incinerators. Despite legislative efforts like HF2445, which set diversion goals of 40% by 2025, progress remains slow. The MPCA estimates that 134,000 to 192,000 tons of textiles are discarded annually, yet only 8,168 tons are recycled. The rise of fast fashion and synthetic fiber production exacerbates this issue, contributing to microplastic pollution, greenhouse gas emissions, and toxic chemical runoff. Nationally, the U.S. generates 17 million tons of textile waste annually, with global projections forecasting a 50% increase by 2030. Alarmingly, less than 1% of textile waste is truly recycled, while 73% is landfilled or incinerated. Polyester, primarily poly(ethylene terephthalate) (PET), dominates 54% of global fiber production, but recycling PET from mixed textile waste, such as polyester-cotton/nylon blends, remains a significant challenge. Mechanical recycling degrades fiber quality, limiting reuse, while chemical depolymerization, though promising, remains challenges like high energy consumption, long reaction times, and unreacted solids persist. Addressing these barriers requires innovative, low-energy recycling technologies to improve efficiency, catalyst sustainability, and industrial scalability, for a circular textile economy and a more resilient waste management system in Minnesota.

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.

We propose developing a catalytic microwave-assisted depolymerization system to efficiently convert mixed textile waste into high-value monomers, enabling closed-loop recycling in the textile industry. Unlike conventional methods, which require high temperatures, long reaction times, and harsh solvents, our system operates under mild conditions (150–200oC) with short processing times, offering a more energy-efficient and environmentally friendly alternative. This innovative approach integrates microwave-assisted heating with tailored heterogeneous microwave-responsive catalysts to selectively break down PET into their constituent monomers, such as bis(2-hydroxyethyl) terephthalate (BHET), while preserving cotton and nylon for separate downstream recovery. The system will utilize green solvents (e.g., alcohols, deep eutectic solvents) to optimize depolymerization efficiency while ensuring sustainability.

Key activities include optimizing a bench-scale depolymerization system, designing microwave-responsive catalysts for enhanced efficiency and recyclability, and conducting techno-economic and life cycle assessments to evaluate scalability and sustainability. This technology directly addresses Minnesota's textile waste crisis, advancing climate resilience and circular economy principles by reducing reliance on virgin petrochemical resources. If successful, it will transform textile recycling, creating sustainable feedstocks for fiber production while significantly reducing landfill waste, microplastic pollution, and greenhouse gas emissions across urban and rural waste streams.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

The proposed project will protect and enhance the state's natural resources by addressing textile waste pollution through sustainable recycling. Key outcomes include: 1) Reducing landfill accumulation of synthetic fibers, mitigating soil and water contamination from microplastics and toxic chemicals. 2) Lowering greenhouse gas emissions by diverting textile waste from incineration and reducing the need for virgin petrochemical-based production. 3) Promoting closed-loop recycling to conserve natural resources, decrease energy consumption, and minimize environmental degradation from raw material extraction and textile manufacturing. The outcomes align with Minnesota's waste management policies, support Minnesota's long-term sustainability and climate reliance initiatives.

Activities and Milestones

Activity 1: Laboratory-scale Process Development of Microwave-Assisted Depolymerization of Mixed Textile Waste

Activity Budget: $160,000

Activity Description:
This activity aims to develop and optimize a bench-scale catalytic microwave-assisted depolymerization system for mixed textile waste recycling. The system will efficiently break down PET into high-value monomers while separating and preserving cotton and nylon for downstream recovery. Optimized solvents and microwave-responsive catalysts will enable depolymerization under mild conditions—atmospheric pressure and relatively low temperatures (150–200 ºC) with short processing times.

A specialized microwave reactor will be designed to enhance energy distribution and absorption efficiency, considering reactor geometry's impact on mass and heat transfer. Key process parameters, including power density, reaction time, and temperature distribution, will be optimized for batch and continuous flow operations. Green solvents (e.g., alcohols, ionic liquids, deep eutectic solvents) will be explored to maximize microwave absorption and depolymerization efficiency, with solvent polarity and microwave absorption capacity analyzed to develop a recyclable, eco-friendly solvent system.

A comprehensive separation strategy will maximize monomer recovery and purity, while protocols for cotton and nylon recovery, potentially via solvent dissolution, will be established. Advanced characterization (HPLC, NMR, FTIR) will monitor monomer yield and reaction kinetics. By the end of this activity, we aim to deliver an optimized bench-scale system with recommendations for scaling up to pilot-scale operations.

Activity Milestones:

Description	Approximate Completion Date
Design and construct a specialized microwave reactor	October 31, 2026
Screen and optimize green solvent systems	December 31, 2026
Optimize process parameters	June 30, 2027
Develop and validate separation protocols for cotton and nylon	October 31, 2027

Activity 2: Development of Heterogeneous Microwave-responsive Catalyst for Enhanced Depolymerization and Scalable Recycling

Activity Budget: $100,000

Activity Description:
Catalysts are crucial for PET depolymerization, but traditional homogeneous metal salts face challenges in separation, recovery, and reuse. This activity focuses on developing highly efficient heterogeneous catalysts to enhance conversion, selectivity, and recyclability. We will design and optimize microwave-responsive metal oxide catalysts with tailored surface properties, high stability, and enhanced microwave absorption. These microwave-responsive catalysts enable faster, selective heating, reducing reaction times, and increasing monomer yields through localized thermal and non-thermal effects. The relationship between microwave absorption and catalytic performance will be analyzed to optimize particle size, surface area, and active site distribution. A structured catalyst approach will immobilize nanoparticles on macroporous supports (e.g., foam, monolith) to improve mass and heat transfer, enable easy separation, and enhance scalability. Catalytic activity, stability, and regeneration will be systematically evaluated over multiple cycles to extend catalyst lifespan. Process conditions, including temperature, reaction time, and catalyst loading, will be optimized to

maximize PET depolymerization efficiency. By the end of this activity, we aim to develop a robust, reusable catalyst system that outperforms conventional counterparts, ensuring cost-effective, scalable PET glycolysis for sustainable textile waste recycling.

Activity Milestones:

Description	Approximate Completion Date
Design and Synthesis of Microwave-Responsive Heterogeneous Catalysts	June 30, 2027
Catalyst Scale-Up through the structured catalyst approach	October 31, 2027
Optimization of Catalyst Performance and Regeneration Protocols	March 31, 2028

Activity 3: Techno-Economic Analysis and Life Cycle Assessment

Activity Budget: $40,000

Activity Description:
As part of this project, we will conduct a techno-economic analysis (TEA) and life cycle assessment (LCA) to comprehensively evaluate the feasibility, economic viability, and environmental impact of the catalytic microwave-assisted depolymerization system for waste textile recycling. These assessments will provide critical insights into process optimization, scalability, and long-term sustainability. TEA will assess the economic feasibility of the technology by analyzing capital expenditures (CAPEX), operational expenditures (OPEX), and overall process economics, thereby providing a financial model to determine the economic sustainability of the technology and guide future industrial-scale deployment. LCA will quantify the environmental impact of the catalytic microwave-assisted depolymerization process across its entire life cycle. The combined TEA and LCA will offer a holistic evaluation of the technology's economic and environmental performance, ensuring that the system is not only financially viable but also aligned with sustainability goals. These assessments will inform further process improvements and support decision-making for large-scale implementation in the textile recycling industry.

Activity Milestones:

Description	Approximate Completion Date
Generate information for TEA and LCA	March 31, 2028
Final Report on this project with outreach materials	June 30, 2028

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
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?

Following successful pilots, we will scale the catalytic microwave-assisted depolymerization system for industrial deployment through market validation and partnerships with textile manufacturers, recycling facilities, and chemical industries. Federal and state funding, including DOE, NSF, and EPA grants, plus public-private partnerships and industry investments will support commercialization. Collaboration with regulatory agencies and local stakeholders will ensure compliance with Minnesota's waste reduction and circular economy initiatives. Outreach programs will engage communities, policymakers, and industry leaders. Our vision is to establish recycling facilities that divert textiles from landfills, reduce pollution and emissions, create jobs, and position Minnesota as a leader in sustainable waste.

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%	0.6		$53,662
Co-PI - summer salary only		oversee specific research			36.6%	0.1		$29,778
Post doc		conduct experiments and analysis			25.9%	2		$165,417
							Sub Total	**$248,857**
Contracts and Services								
TBD	Internal services or fees (uncommon)	chemical analysis				-		$4,000
							Sub Total	**$4,000**
Equipment, Tools, and Supplies								
	Equipment	components	for lab system development and testing					$24,000
	Tools and Supplies	lab and miscellaneous supplies, including catalysts, chemicals, consumable supplies for analytical instruments, gloves, masks	for personnel to accurately and safely conduct the research proposed					$21,143
							Sub Total	**$45,143**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								

							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging		to collect feedstock textiles and to provide demonstrations					$2,000
							Sub Total	**$2,000**
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: bbe6c6c0-16c.pdf

Alternate Text for Visual Component

This project develops a catalytic microwave-assisted depolymerization technology that integrates microwave-responsive heterogeneous catalysts and environmentally friendly solvents to selectively break down polyesters into high-value monomers under mild operating conditions. This innovative approach provides an energy-efficient, scalable, and sustainable pathway for closed-loop textile recycling, advancing circular economy principles....

Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	34c878d1-125.pdf
Audit	a3cfe2fe-125.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