Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-225

Proposal Title: Converting Agricultural Waste to Biodegradable Plastics and Biofuel

Project Manager Information

Name: Bo Wang

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

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Project Basic Information

Project Summary: Corn stover, a major agricultural residue, will be pretreated and enzymatically digested to generate sugars, and then converted to biodegradable plastics and bio-gasoline through microbial fermentation and process engineering.

ENRTF Funds Requested: $794,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Energy (E)

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

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

Current production of biofuels (including ethanol and biodiesel) in Minnesota mainly relies on feedstocks such as soybean and corn, which directly competes with our food supply chain. In addition, the energy density of ethanol is relatively low (27 MJ/kg vs. 43 MJ/kg of gasoline) which limits its application as fuel for conventional internal combustion engine (blending ratio ≤15% in gasoline). Therefore, developing biofuels with relatively high energy density from cheap inedible biomass is a more promising route for energy sustainability.

Corn stover (leaves, stalks, cobs) is a type of lignocellulosic biomass that accounts for 70% of agricultural residue, and about 4 tons/acre of corn stover is generated on corn fields in Minnesota. Various technologies have been developed to hydrolyze the stover raw material to monomer sugars that can be utilized through microbial fermentation to produce biofuels and other valuable products. However, the process encompassing stover hydrolysis and microbial fermentation has not been streamlined due to the complexity and need of multidisciplinary expertise. For instance, stover hydrolysates may contain certain compounds that inhibit the microbial fermentation of biofuels. Orchestrating stover hydrolysis and microbial fermentation is critical to boosting yield and productivity of biofuels and hence commercializing the technology.

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 using a systems engineering approach to develop a bioprocess that streamlines conversion of corn stover to medium-chain-length polyhydroxyalkanoates (mcl-PHA) and bio-gasoline. mcl-PHA is a type of energy-rich biopolymer with building-blocks containing 6–14 carbons. It is naturally synthesized as energy-storage compounds in some microbes, and can be used as biodegradable, biocompatible, and environment-friendly thermoplastics with properties comparable to conventional plastics. Note that mcl-PHA' energy density (34 MJ/kg) is comparable to that of butanol (34 MJ/kg) and biodiesel (37.5 MJ/kg) and can be readily converted to bio-gasoline through methyl esterification or hydrothermal liquefaction (HTL). We will first hydrolyze corn stover to hydrolysate (mostly monomer sugars) through ionic liquid pretreatment plus enzymatic digestion. Ionic liquids are non-volatile solvents that can be designed to dissolve and pretreat stover, and can be recycled and reused in the process for multiple times. The hydrolysates will be tested for their capacity in supporting microbes' growth and biosynthesis of PHA. Particularly, industry-relevant bacterium, Pseudomonas putida, will be engineered to achieve efficient utilization of the stover hydrolysate for production of PHA. Finally, the best performing strains with highest PHA contents will be tested for production of bio-gasoline through one-step transesterification or HTL.

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?

Owing to PHA's biodegradability, biocompatibility and comparable properties relative to conventional plastics, PHA have diverse applications, such as in making disposable utensils, packaging materials, paper coating, mulching film, drug delivery and medical implants. Further transforming energy-rich mcl-PHA into bio-gasolines (via transesterification or HTL) will provide a gasoline supplement that has higher energy density than ethanol. Large-scale production and application of PHA and the derivative biofuels will not only prevent plastic/fuel usage from polluting the environment, but also make use of the corn stover, reducing greenhouse gas emissions from the corn fields (due to stover degradation) while rendering energy sustainability.

Activities and Milestones

Activity 1: Pretreating lignocellulose biomass by ionic liquids followed by enzymatic hydrolysis to generate ready-to-use hydrolysates for microbial biomanufacturing

Activity Budget: $157,290

Activity Description:
The effectiveness of biomass pretreatment is essential to the hydrolysis of biomass. We will pretreat biomass by heating it in ionic liquids at 80–100 °C for a different period of time (up to 4 hours). After purifying the pretreated biomass, we will compare structural changes of cellulose before and after the pretreatment by X-ray powder diffraction (XRD; to determine crystallinity), FT-IR (for crystallinity index), and Scanning Electron Microscopy (SEM; for surface morphology changes).

Furthermore, we will conduct the one-pot simultaneous hydrolysis of cellulose and hemicellulose catalyzed by enzymes. We will use a mixture of enzymes containing cellulase and hemicellulase, and immobilize enzymes on solid carriers such as silica sol-gel matrices, chitosan, and polystyrene beads with glutaraldehyde as the cross-linking agent. We will examine several key factors including substrate pretreated by different solvents, substrate loading, enzyme concentration, reaction temperature, and product inhibition. Sugars will be analyzed by commercial assays and/or the HPLC method.

To minimize the cost, we will recycle and reuse ionic liquids for multiple cycles, and conduct cost and effectiveness analysis for recycling. For the optimized process, we will conduct technoeconomic analysis to evaluate the cost-effectiveness and feasibility of our new pretreatment system on a large scale.

Activity Milestones:

Description	Approximate Completion Date
Pretreat biomass by ionic liquids	December 31, 2026
Determine structural changes of biomass upon pretreatment	June 30, 2027
Compare enzymatic hydrolysis of biomass with or without pretreatment	December 31, 2027
Adjust biomass pretreatment and hydrolysis according to feedback from PHA fermentation results	June 30, 2028

Activity 2: Systems metabolic engineering of bacterium Pseudomonas putida to convert lignocellulose hydrolysates to polyhydroxyalkanoates and biofuels

Activity Budget: $356,124

Activity Description:
Bacterium strain Pseudomonas putida KT2440, which is known to biosynthesize small amount of medium-chain-length polyhydroxyalkanoates (mcl-PHA) under nitrogen-limited conditions, will be genetically engineered to augment its capability of biosynthesizing mcl-PHA using lignocellulose hydrolysates as the carbon and energy sources.

We will combine synthetic biology and systems biology approaches to establish a repeatable systems metabolic engineering workflow – the Design-Build-Test-Learn (DBTL) cycle, to accelerate our understanding of the energy and carbon flow within P. putida cells and our endeavor in modifying this microorganism to produce mcl-PHA and hence biofuels. The 'Design' step will be facilitated with genome-scale modeling to sketch an ideal metabolic blueprint for maximum biosynthesis of PHA. The 'Build' step will be implemented through engineering the genome of cells using state-of-the-art synthetic biology tools such as CRISPR/Cas. The 'Test' step will encompass cell cultivation, analysis of substrate consumption and product formation rates, etc. The 'Learn' step will include metabolomics and metabolic flux analysis which will reveal resource allocation within cells, providing imperative guidance for the next round of ‘Design’ efforts.

The best PHA-producing P. putida strain will be tested for production of 3-hydroxyalkanoate methyl esters (HAMEs), i.e., bio-gasoline, using the same method as industrial production of biodiesel (FAMEs).

Activity Milestones:

Description	Approximate Completion Date
Enable Pseudomonas to utilize stover hydrolysate sugars through genome engineering and adaptive laboratory evolution	December 31, 2026
Demonstrate production of PHA by engineered Pseudomonas strain using lignocellulosic biomass hydrolysate	June 30, 2027
Genome-scale modeling, metabolomics and 13C-metabolic flux analysis (MFA) to identify targets that limit PHA biosynthesis	December 31, 2027
Genetically engineer Pseudomonas to remove competing pathways and metabolic bottlenecks; PHA ≥50% cell dry weight	June 30, 2028
Metabolomics and 13C-MFA to identify additional targets that limit biosynthesis of PHA in engineered Pseudomonas	December 31, 2028
Genetically re-engineer Pseudomonas to remove competing pathways and metabolic bottlenecks; PHA ≥75% cell dry weight	June 30, 2029

Activity 3: Hydrothermal Liquefaction of PHA-Producing Strain Biomass into Bio-crude

Activity Budget: $280,586

Activity Description:
This task aims to develop a preliminary optimized hydrothermal liquefaction (HTL) process to convert biomass from the PHA-producing strain constructed in Activity 2 into bio-crude. A lab-scale HTL reactor will be developed, and HTL experiments will optimize key parameters—including temperature (240–370°C), pressure, residence time, and catalysts - to maximize bio-crude yield and quality.

We will investigate the effects of biomass composition on bio-crude properties, focusing on improving higher heating value (HHV) and reducing heteroatom content. We will develop catalysts such as zeolites, NiMo/Al2O3 and alkaline to increase bio-crude oil yields, and employ catalyst separation and reuse strategies to improve process efficiency.

The HTL process will be evaluated for efficiency, stability, and scalability. A mass and energy balance will be established, alongside a preliminary techno-economic analysis to assess feasibility at scale.

To enhance predictive capabilities, a multiphase component additivity (MCA) model will be developed, integrating the average oxidation state (AOS) of PHA to correlate biomass composition with HTL product yields and quality.

This research will deliver a preliminary optimized HTL process, a validated predictive model, and recommendations for integrating HTL into biorefineries. These advancements will support the sustainable production of bio-crude from PHA-producing microorganisms for low-carbon biofuels.

Activity Milestones:

Description	Approximate Completion Date
Develop and optimize lab-scale HTL reactor for processing PHA-containing biomass	June 30, 2027

Test various catalysts and optimize HTL parameters (temperature, pressure, and time) for bio-crude production	April 30, 2028
Establish mass and energy balance and conduct techno-economic analysis	October 31, 2028
Develop MCA model for biocrude yield prediction	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Hua Zhao	University of Minnesota	Professor, Co-PI	Yes
Roger Ruan	University of Minnesota	Professor, Co-PI	Yes

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?

The proposed research will be carried out at the Department of Bioproducts and Biosystems Engineering at University of Minnesota. After successful demonstration of the technology at lab scale at the end of the project, the technology will be licensed to (startup) biotech companies. Additional funding for further scaling up the project will be sought through the Minnesota Department of Agriculture, Minnesota Department of Transportation, Minnesota biofuel companies, and federal funding agencies such as USDA, NSF, and DOE.

Project Manager and Organization Qualifications

Project Manager Name: Bo Wang

Job Title: Assistant Professor

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

Bo Wang is a tenure-track assistant professor at the Department of Bioproducts and Biosystems Engineering at the University of Minnesota (UMN). Bo is also a member of the BioTechnology Institute which aims to advance multidisciplinary research and innovation at the forefront of biotechnology. Bo earned his Bachelor's and Master's degrees in Chemical Engineering from Tsinghua University and his Ph.D. degree in Biological Design from Arizona State University. He was a postdoctoral fellow and research scientist at the National Renewable Energy Laboratory, and worked as a research assistant professor at Vanderbilt University before he joined UMN in August 2024.

Bo has extensive research experience in renewable energy, biofuel, and bioproducts. His professional background includes synthetic biology, metabolic engineering, and chemical engineering, which qualifies him to take the lead in coordinating the entire project. His current research is focused on understanding and engineering the metabolism of microorganisms to produce biofuel, bioplastics, and value-added bioproducts from renewable resources, such as agricultural waste, solar energy and CO2. Bo has authored about 20 articles in prestigious peer-reviewed journals such as Nature Communications, Metabolic Engineering, and Green Chemistry. He has also authored one book chapter, and has been awarded three U.S. patents.

Bo has participated as key personnel in multiple federal grants before he joined University Minnesota. At the University of Minnesota, Bo is a Principal Investigator who is managing a startup fund of $500,000 and a lab space of 1000 SF. He is currently a mentor for a graduate student from the Microbial Engineering graduate program, and two Ph.D. students from the Bioproducts and Biosystems Science, Engineering and Management graduate program are going to join Bo's Metabolic Engineering & Synthetic Biology Lab in Fall 2025.

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

Organization Description:

In the College of Food, Agricultural and Natural Resources Sciences (CFANS) at the University of Minnesota, we look at the bigger picture. When we envision a better tomorrow, it includes disease-resistant crops, products that protect our health, lakes free from invasive species, and so much more. We use science to find answers to Minnesota and the world's grand challenges and solve tomorrow's problems. Almost 93 percent of students who earn CFANS undergraduate degrees find jobs in their career field or enter graduate school within six months of graduation.

The Department of Bioproducts and Biosystems Engineering, in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

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

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Lead PI/Assistant Professor - 2 weeks summer salary annually		oversee and direct all research components and one specific area and respective team			36.6%	0.12		$20,672
graduate students		design and carry out experiments in each of three research areas			83.6%	4.5		$497,777
Postdoctoral student		Assist Co-PI, design and carry out experiments in one research area			25.9%	1.5		$98,533
Co-PI/Professor - 2 weeks summer salary annually		oversee specific part of research and team working on that aspect			36.6%	0.12		$35,557
							Sub Total	**$652,539**
Contracts and Services								
manufacturer or other	Service Contract	repairs and maintenance for two labs with equipment being used				-		$12,000
							Sub Total	**$12,000**
Equipment, Tools, and Supplies								
	Tools and Supplies	lab supplies to include chemicals, reagents, pipettes, test tubes, gloves, protective eyewear, masks, etc	to conduct research and keep assigned staff safe					$103,461
							Sub Total	**$103,461**
Capital Expenditures								
		Ruan team purchase	The HTL batch reactor is essential for conducting hydrothermal liquefaction	X				$20,000

			experiments to convert PHA-producing strain biomass into bio-crude, and for establishing mass and energy balances for techno-economic analysis.					
							Sub Total	**$20,000**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	3 teams	For presenting the project outcomes, learning from peers in the relevant research fields, educating students and postdoctoral researchers at meetings and conferences held within Minnesota.					$6,000
							Sub Total	**$6,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$794,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		Ruan team purchase	necessary to conduct this research **Additional Explanation :** The HTL batch reactor will be purchased following the same university equipment purchasing procedures through bidding, etc. and it will remain a core component at the University of Minnesota, supporting this LCCMR research in bio-crude production and renewable energy. It will be used continuously for similar projects, including future LCCMR and other studies on biomass conversion and catalyst development, not only for the duration of this project but also for years to come. This equipment will also support educational activities and foster future collaborations in renewable energy and sustainable fuels.

Non ENRTF Funds

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

Total Project Cost: $794,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 969e8270-be2.pdf

Alternate Text for Visual Component

Schematic illustration of the integrated engineering strategy for converting agricultural residue, i.e., corn stover, to renewable biodegradable plastics and biofuel....

Supplemental Attachments

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

Title	File
Letter of Authorization to Submit	4807447b-609.pdf
Audit	c8ba7d9b-545.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

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

Yes, I understand