Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-057

Proposal Title: Converting Corn Stover to Sugars via Effective Pretreatment

Project Manager Information

Name: Hua Zhao

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

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Project Basic Information

Project Summary: This project will develop a cost-effective pretreatment method for corn stover in Minnesota, leading to efficient hydrolysis of cellulose and hemicellulose to cellulosic sugars, which are used to produce biofuels.

ENRTF Funds Requested: $398,000

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?

During the Project and In the Future

Narrative

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

Ethanol is a valuable biofuel for making gasoline blends and sustainable aviation fuel (SAF). Minnesota is one of the top corn ethanol producing states with 18 ethanol plants and a combined production capacity of over one billion gallons. In addition, Minnesota has the most E85 (51% to 83% ethanol) stations in the nation. With the rising need for producing more SAF, it is urgent to re-exploit cellulosic biomass to meet the zero-carbon footprint requirement and also much higher sugar and ethanol demands. Corn stover and cobs are rich in cellulosic biomass and a large portion of corn stover is available as valuable bioresource.

Releasing sugars from cellulosic biomass is much harder than from starch. Starch has a relatively open structure because it contains both semicrystalline and amorphous regions. On the contrary, cellulose has a very compact structure due to its high crystallinity, and on top of that, cellulose in nature is bonded to hemicellulose and wrapped around by lignin. Both cellulose and hemicellulose can yield fermentable sugars upon hydrolysis. Thus, a cost-effective pretreatment method to open up cellulose structure and remove lignin is the key to turning cellulosic biomass into sugars, which can be fermented to ethanol and other biofuels.

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.

To open up the structure of cellulosic biomass, there are various pretreatment methods including biological, physical, chemical, and physiochemical processes, however, each of these methods has some disadvantages such as high costs, time consuming, low efficiency, and environmental concerns. Our research group plans to develop a cost-effective biomass pretreatment method followed by simultaneous enzymatic hydrolysis of cellulose and hemicellulose to sugars. Specifically, we will develop two inexpensive solvent systems for corn stover pretreatment: (1) a special type of Deep Eutectic Solvents (DES) made of inexpensive glycols with inorganic salts, or (2) “solvate” ionic liquids consisting of glyme complexes with salts carrying Lewis basic ions (such as chloride and acetate). Glymes are glycol diethers. Glycols and selected glymes are readily biodegradable and have low environmental impact. Previously, cellulosic biomass was treated by different DES based on choline chloride (or other ammonium and phosphonium salts) paired with glycols/glycerol/acids at over 100 °C to break down and removal lignin. However, choline chloride and other ammonium salts are not stable and decompose at high temperatures (e.g., 100 °C or higher). Our approach will use more stable inorganic salts to form complexes with glycols or glymes.

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 successful completion of this project will result in a cost-effective method for efficient pretreatment of corn stover, which is readily available in Minnesota. The current corn ethanol producers are based on corn starch technology, but our method allows for the release of sugars from cellulosic biomass in corn stover. We will develop new low-cost solvent systems that will enable effective treatment of cellulose and removal of lignin so that sugars can be readily released from biomass by enzymes. This will afford much more fermentable sugars with zero or low carbon footprint to the biofuel industry in Minnesota.

Activities and Milestones

Activity 1: Develop and characterize new and inexpensive solvent systems based on glycols and glymes

Activity Budget: $128,413

Activity Description:
To disrupt cellulose's compact crystalline structure, the solvent must possess some unique properties such as the ability to break the hydrogen-bonding network. We plan to develop two types of inexpensive solvent systems: (1) Deep eutectic solvents (DES) by mixing commercial glycols (e.g., PEG 200-500) with inorganic salts (e.g., lithium chloride and lithium acetate), and (2) Glyme complexes with chloride or acetate salts. Previously, DES were prepared by mixing ethylene glycol or glycerol with choline chloride, lithium chloride, phosphonium or ammonium salts, diethylene glycol with ammonium or phosphonium salts, or polyethylene glycol with organic salts; eutectic mixtures were produced because glycols form hydrogen bonds with anions such as chloride. Glymes behave like crown ethers, so they can coordinate with alkali metal ions (such as lithium and sodium cations) and yield complexes (known as "solvate" ionic liquids). We will further characterize these neoteric solvents by NMR (nuclear magnetic resonance), FT-IR (Fourier-transform infrared spectroscopy), DSC (Differential Scanning Calorimetry), TGA (Thermogravimetric Analysis), and viscosity measurements. Dr. Gary Baker at the University of Missouri will support the DCS and TGA analysis.

Activity Milestones:

Description	Approximate Completion Date
Develop deep eutectic solvents based on glycols and inorganic salts	December 31, 2026
Develop glyme complexes with inorganic salts	June 30, 2027
Characterize new solvents by NMR, FT-IR, DSC, TGA, and viscosity measurements	June 30, 2027

Activity 2: Determine structural changes of cellulose pretreated by new solvent systems

Activity Budget: $133,545

Activity Description:
The effectiveness of cellulose pretreatment is essential to the hydrolysis of biomass. An effective pretreatment leads to more open cellulose structure and a lower lignin content. We will pretreat pure cellulose (e.g., Avicel PH-101) by heating it in new solvents at 80–100 °C for a different period of time (up to 4 hours). After purifying the pretreated cellulose, 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). In addition, the porosity and openness of cellulose structure will be examined by enzyme adsorption isotherm using cellulase; this will inform us how strong the enzyme binds to cellulose and how efficient the subsequent cellulose hydrolysis is. Dr. Gary Baker at the University of Missouri will support the XRD and SEM analysis of cellulose samples. Furthermore, we will conduct the enzymatic hydrolysis of cellulose with or without pretreatment catalyzed by the enzyme (cellulase), and compare the impact of pretreatment on the hydrolysis rate. The glucose concentration will be measured by the glucose HK assay (from Sigma-Aldrich).

Activity Milestones:

Description	Approximate Completion Date
Pretreat cellulose by new solvent systems	December 31, 2027
Determine structural changes of cellulose upon pretreatment	June 30, 2028
Compare enzymatic hydrolysis of cellulose with or without pretreatment	June 30, 2028

Activity 3: Evaluate the impact of pretreatment on corn stover's simultaneous hydrolysis of cellulose and hemicellulose

Activity Budget: $136,042

Activity Description:
We will collect at least five corn stover/cob samples from different corn fields. We will conduct biomass composition analysis for each corn stover sample. We will pretreat each corn stover sample and characterize their structural changes following methods described in Activity 2. Dr. Gary Baker at the University of Missouri will support the XRD and SEM analysis of cellulosic biomass samples.

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 the solvents for multiple cycles, and conduct cost and effectiveness analysis for reused solvent systems. For the optimized process, we will conduct technoeconomic analysis to evaluate the cost-effectiveness and feasibility of our new pretreatment systems on a large scale.

Activity Milestones:

Description	Approximate Completion Date
Determine structural changes of corn stover upon pretreatment by new solvent systems	September 30, 2028
Conduct simultaneous enzymatic hydrolysis of cellulose and hemicellulose after pretreatment	June 30, 2029
Conduct technoeconomic analysis for the new biomass pretreatment process	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Gary A. Baker	University of Missouri	Assist with the analysis and characterizations of new solvents and cellulosic biomass samples	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?

Hua Zhao and his students will lead the research design and experiments to implement proposed activities. Their collaborator Dr. Gary Baker will be funded by different sources. Results generated in this project will enable a fundamental understanding of solvent pretreatment on structural changes of cellulosic biomass, and a practical aspect of how cost-effective pretreatment can lead to an efficient release of sugars from biomass. The preliminary data generated by this study will allow us to acquire a larger NSF, DOE or USDA grant that involves multiple institutions to tackle a bigger scale of cellulosic biomass utilization and biofuel production.

Project Manager and Organization Qualifications

Project Manager Name: Hua Zhao

Job Title: Professor and Department Head

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

The PI received a combined education in both chemistry (bachelor's degree) and chemical engineering (master's and doctoral degrees). He has over 20 years of experience in studying enzymatic reactions/processes using various enzymes and DNA-based hybrid catalysts. His research projects include biomass conversion to biofuels and biomaterials, biodiesel preparation, polyester synthesis, biosurfactants, asymmetric catalysis, desulfurization of liquid fuels, coal liquefaction, PFAS elimination, and carbon dioxide capture and utilization, etc. His research group developed new solvent systems (e.g., ionic liquids and deep eutectic solvents) that are highly compatible with enzymes; in particular, he designed so-called 'water-like' ionic liquids to activate and stabilize enzymes. His group provided some fundamental understanding of how ionic solvents interact with enzymes through different mechanisms such as ion specificity (Hofmeister's series), hydrogen bonding basicity, hydrophobicity, and polarity, etc. He has published about 100 journal papers and book chapters with high citations (h-index = 44 based on Google Scholar). His research has been supported by NSF, NIH, ACS-PRF, and LCCMR. He received the prestigious Henry Dreyfus Teacher-Scholar Award from Camille and Henry Dreyfus Foundation.

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								
One graduate student (stipend, tuition and fringe benefits for three years)		Research design and conduct experiments as proposed			12.6%	1.5		$179,503
Two undergraduate students ($16.95 per hour, 10 hour per week, and 20 weeks each year; 3% increase in each year afterwards)		Receive research training and collect experimental data			0%	0.75		$20,961
Research associate at 0.5 FTE (salary and fringe benefits)		Support research design and mentor graduate and undergraduate students			20.6%	1.5		$122,266
							Sub Total	**$322,730**
Contracts and Services								
Sample analysis by DSC, TGA, XRD and SEM	Service Contract	New solvents are characterized by DSC and TGA, and biomass samples by XRD and SEM at the collaborator's lab (with low costs).				0.3		$9,000
							Sub Total	**$9,000**
Equipment, Tools, and Supplies								

	Tools and Supplies	Funds ($20,000 in Year 1, $20,000 in Year 2, and $20,000 in Year 3) are requested to purchase laboratory chemicals (glymes, glycols and salts), reagents (acetone, methanol, and HPLC-grade water), enzymes (cellulases), and reagents (sugar assays).	These chemicals and enzymes are needed to carry out the proposed experimental work.					$59,270
							Sub Total	**$59,270**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Conference Registration Miles/ Meals/ Lodging	One conference trip per year for PI and two students per year, $150 registration per person ($450 total per year), 200 miles per year ($150), and meals and other costs ($400 for 3 persons, two days per year).	PI and two students each year will present and share research results in in-state conferences, and network with peers.					$3,000
							Sub Total	**$3,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Open-access journal publication cost	Publish research results in open-access journal, $2,000 per year for two papers					$4,000
							Sub Total	**$4,000**
Other Expenses								
							Sub Total	**-**

							Grand Total	**$398,000**

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: $398,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: ce8f0759-83f.docx

Alternate Text for Visual Component

Corn stover will be pretreated by new low-cost solvent systems prior to effective enzymatic hydrolysis of cellulose and hemicellulose to release fermentable sugars....

Supplemental Attachments

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

Title	File
Audit	39a9b063-643.pdf
UMn Sponsored Projects Office Letter of Approval to Submit	078e9246-40d.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

Yes, I understand