Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-186

Proposal Title: Resilient Farms Using Green Ammonia-Fueled Equipment

Project Manager Information

Name: Will Northrop

Organization: U of MN - College of Science and Engineering

Office Telephone: (612) 625-6854

Email: wnorthro@umn.edu

Project Basic Information

Project Summary: Advanced engine technology will be developed to cleanly consume green ammonia or propane with low emissions. A farm utility tractor will be converted and demonstrated to prove the technology.

ENRTF Funds Requested: $784,000

Proposed Project Completion: June 30, 2028

LCCMR Funding Category: Energy (E)

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

Narrative

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

Modern farms predominantly use diesel fuel for tractors and other motorized implements. Diesel fuel does not originate in Minnesota and is costly to farmers. Green ammonia locally produced by converting stranded wind electricity resources into hydrogen can be accomplished locally and provide a reliable source of fuel and fertilizer. A study by UMN showed that if green ammonia is reduced to $500 per metric ton, the cost per BTU of energy would be lower than the current diesel price. Propane is already used as a fuel on farms, and if equipment can flexibly operate on ammonia or propane, farmers can mitigate price fluctuations by switching between fuels. Green ammonia, a fuel that contains no carbon, also reduces emissions compared to hydrocarbon fuels. However, ammonia is slow burning and is challenging to combust cleanly in engines. In 2019, with funding from the LCCMR, the UMN team converted a utility tractor to ammonia/diesel dual fuel and demonstrated it on a working farm. This demonstration showed that converting engines to ammonia operation is possible, but 100% ammonia operation was challenging. The diesel dual fuel tractor also resulted in excessive NOx and unburned ammonia emissions that were difficult to mitigate.

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.

Since 2019, UMN has developed a 100% ammonia combustion engine technology that does not require diesel as a secondary fuel. The pure ammonia engine is currently being developed for stationary electrical generator applications. It will be adapted for off-road vehicle use in the proposed work. Beyond demonstrating pure ammonia operation in a utility tractor, the proposed project will develop a new technology to allow the vehicle to operate on either ammonia or propane, depending on farmer preference and/or fuel cost. Propane and ammonia are stored as liquids at the same pressure and use the same fuel transfer plumbing and controls. Propane could either be fossil-derived or from renewable sources. In the project, the UMN team will develop and prototype a variable intake timing system for the engine that reduces the compression ratio when propane is operated to avoid knocking and increases the compression ratio for ammonia to overcome fuel ignition resistance. Aftertreatment to eliminate unburned fuel in the exhaust will be developed and demonstrated in the project. The ammonia flexible fuel engine will be installed in a restored utility tractor as part of the project and demonstrated performing work on a functioning farm.

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?

Resilient farms in Minnesota must both operate profitably and protect the environment. Both ammonia and propane are clean burning fuels that result in lower emissions than diesel fuel. Emissions of smoke, unburned hydrocarbons, and nitrous oxides harm human health and the living ecosystem. Storing wind and solar energy is also key to an efficient and effective energy system. Using ammonia for energy storage is much more cost-effective than batteries and other forms of storage. If green ammonia is produced from wind and solar, it can be stored and used seasonally, providing a comprehensive, dynamic, and year-round clean energy

Activities and Milestones

Activity 1: Develop engine technology to flexibly combust both ammonia and propane

Activity Budget: $239,707

Activity Description:
A combustion system will be developed for a 4-cylinder industrial engine to allow operation on propane or ammonia. This activity will implement an adjustable intake valve timing strategy previously conceptualized by the UMN team. A single-cylinder laboratory engine installed on a dynamometer at the UMN MERL will be used to develop the combustion strategy with already developed ammonia capability. A control system will also be developed to switch from one fuel to another when the engine is turned off. All systems will be proven on the lab engine before being installed on a vehicle.

Activity Milestones:

Description	Approximate Completion Date
Prototype design of engine intake system adjustable valve timing mechanism constructed.	February 28, 2027
Emissions and performance characterization on both ammonia and propane completed on single-cylinder test engine	April 30, 2027
Final parts and control of adjustable valve timing mechanism built for multi-cylinder engine.	June 30, 2027

Activity 2: Build and validate ammonia flex fuel tractor

Activity Budget: $439,646

Activity Description:
A utility tractor of practical size for small farming operations will be selected for conversion to flexible fuel ammonia/propane operation. Older models of tractor with built-in propane tanks are preferred for ease of conversion and packaging of the fuel system. The tractor will be completely renovated and updated with features compatible with modern farm operations. A multi-cylinder version of the flexible fuel engine will be installed in the tractor, including aftertreatment and a custom driver user interface.

Activity Milestones:

Description	Approximate Completion Date
Utility tractor procured and restored without engine installed.	April 30, 2027
Multi-cylinder engine and aftertreatment completed for installation in utility tractor	August 31, 2027
Tractor operation validated on a PTO dynamometer with emissions verification.	March 31, 2028

Activity 3: On-field demonstration of ammonia flex fuel tractor

Activity Budget: $104,647

Activity Description:
A Minnesota farm with access to anhydrous ammonia and propane will be chosen for the final demonstration during the project. Work will be conducted to upfit the farm facility with safe and reliable fuel refilling equipment for the tractor. Outreach activities will ensure that the demonstration is publicized widely. Finally, commercialization analysis will be conducted to determine potential market size and cost of limited production of the fuel flexible tractor for consumer use. The analysis will also consider regulations and standards required for sale of the ammonia tractor long term.

Activity Milestones:

Description	Approximate Completion Date
Farm site selected for demonstration and refueling capability installed.	March 31, 2028
Public demonstration of ammonia/propane flexible fuel tractor	April 30, 2028
Commercialization analysis completed including cost estimate, regulatory requirements, and market	June 30, 2028

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?

After project completion, the flexible fuel ammonia/propane tractor will continue to be demonstrated and shown at agricultural events nationwide. The previous demonstration tractor funded by LCCMR in 2019 received international attention; photos of it are still prolific online. Depending on demand from potential customers, utility tractors will be developed and marketed by Aza Power Systems, a small startup company dedicated to commercializing ammonia powered vehicles and generators. Aza has exclusive rights to ammonia engine technology developed at UMN. After successful demonstration, Aza will fund the commercial development of engines and tractors for sale in the U.S. and abroad.

Project Manager and Organization Qualifications

Project Manager Name: Will Northrop

Job Title: Professor and Director, TE Murphy Engine Research Laboratory

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

Dr. Northrop directs the Thomas E. Murphy Research Laboratory at the University of Minnesota (UMN). He has served as PI on three previous LCCMR projects, each resulting in significant demonstrations, including the 2019 demonstration of a diesel/ammonia dual-fuel tractor. He brings decades of experience in research project management and currently manages a program with expenditures of over $1M per year from industry, state, and federal sources. Dr. Northrop holds multiple U.S. and international patents and has co-authored over 100 peer-reviewed publications since 2009. He is co-founder and senior technical advisor to Aza Power Systems, LLC, a company dedicated to commercializing Minnesota-funded technology in ammonia combustion. In part due to Dr. Northrop's efforts, the UMN is known internationally as a center of excellence for ammonia energy technology.

In the proposed project, Dr. Northrop will lead the technical effort to develop the adjustable valve timing system necessary to operate the engine on both ammonia and propane. He will also lead the integration of the ammonia engine and fuel system, working with external suppliers. Dr. Northrop has a well-qualified group of students and staff whom he will manage to meet the proposed project milestones.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota (U of M) is a leading public research institution committed to advancing knowledge, fostering innovation, and promoting community engagement. With over 50,000 students across its Twin Cities and regional campuses, U of M offers a diverse range of academic programs and interdisciplinary research opportunities. Its world-class faculty and researchers are dedicated to addressing global challenges in health, technology, agriculture, and the environment. The university boasts state-of-the-art facilities and strong collaborations with industry, government, and non-profit organizations, positioning it as a hub for cutting-edge research and transformative solutions. U of M is committed to driving societal impact through discovery and education.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Will Northrop		Principal Investigator			26.79%	0.14		$44,638
Seamus Kane		Researcher			26.79%	2		$271,533
Undergraduate Researchers		Undergraduate Researchers			0%	0.38		$14,400
Research Assistants		Graduate Students			43.01%	1		$122,664
							Sub Total	**$453,235**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	1) Fuel and lubricants, 2) Fuel system, 3) Combustion system, 4) Control system for engine, 5) Computing, 6) Misc plumbing and electrical	The materials and tools are required to complete the engine conversion process and demonstration utility tractor rebuild for fuel flexible operation					$66,362
							Sub Total	**$66,362**
Capital Expenditures								
		1x Utility tractor and 1 x ammonia storage tank for demonstration	The utility tractor and ammonia storage tank are necessary for the demonstration phase of the project	X				$24,700
							Sub Total	**$24,700**
Acquisitions and Stewardship								
							Sub Total	-
Travel In Minnesota								

	Miles/ Meals/ Lodging	Travel to farm site (to be decided) within Minnesota including transportation of demonstration vehicle, rental vehicle, mileage, meals and expenses, and lodging. Approx 3 people for 2 weeks + transport	In-state travel is required to demonstrate the vehicle at a farm site to achieve the final milestone of the proposed project.					$10,000
							Sub Total	**$10,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication of 1 open access journal paper and other miscellaneous media sources	The purpose of the publications is to increase the exposure of this project's outcomes to the broader community.					$4,000
							Sub Total	**$4,000**
Other Expenses								
		Scientific and Engineering Services	These services are for completing the build and machining of the fuel flexible engine, renovation and rebuild of the utility tractor, and calibration of emissions measurement equipment.					$225,703
							Sub Total	**$225,703**
							Grand Total	**$784,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		1x Utility tractor and 1 x ammonia storage tank for demonstration	The listed capital equipment is necessary to complete the project milestones. Without the equipment, the project will not have the envisioned impact on energy systems in Minnesota and prove that farms can use alternative fuels to improve profitability and resiliency. **Additional Explanation :** The capital equipment is the foundation for the work to be completed in the project. The equipment will used throughout the project and after project completion as a demonstration and prototype for commercial development.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	Unrecovered F&A calculated at 54% MTDC	Support of ME facilities where research will be conducted.	Secured	$390,288
			Non State Sub Total	**$390,288**
			Funds Total	**$390,288**

Total Project Cost: $1,174,288

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 5cf69d88-8c6.pdf

Alternate Text for Visual Component

Figures to support the narrative. Photos of previous projects and current laboratory capabilities are shown, and price support for ammonia and propane is given in charts....

Supplemental Attachments

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

Title	File
UMN Letter of Intent	2a4831ea-9d4.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?

No

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

N/A

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

N/A

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:

Victoria Troxler, Sponsored Projects Administration at UMN; Alex Sullivan, Pre-awards Specialist at UMN Department of Mechanical Engineering

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