Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-220

Proposal Title: Sustainable and Eco-Friendly Grain Drying Using Ammonia-Fired Technology

Project Manager Information

Name: Sayan Biswas

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: This proposal aims to demonstrate a reliable, cost-effective, and efficient 100% ammonia burner technology for grain drying applications, utilizing a preheated catalytic bed and high-pressure ammonia-air mixture.

ENRTF Funds Requested: $250,000

Proposed Project Completion: June 30, 2027

LCCMR Funding Category: Small Projects (H)

Secondary Category: Air Quality, Climate Change, and Renewable 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 and In the Future

Narrative

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

Drying grain is a high-energy process that typically relies heavily on fossil fuels or electricity generated burning fossil fuels, contributing significantly to both energy consumption and carbon emissions. Post-harvest, on-farm grain storage plays a crucial role in the supply chain, particularly with market deregulation. It serves as a means of protecting income by offering storage flexibility and enabling growers to select optimal marketing options based on premium prices. The choice of fuel for grain drying is a critical factor for on-farm grain drying, with most operations currently relying on fossil fuels like natural gas, propane, or diesel. However, this practice contributes to greenhouse gas emissions, stemming from the combustion of these fuels, along with increasing cost of fossil fuel, which is unsustainable in the long term. To address this issue, we propose to utilize carbon-free green ammonia as a fuel for grain drying. Since ammonia is already available on farms, leveraging it as a fuel source promotes both agricultural growth and carbon emission reduction. However, ammonia is not inherently an efficient fuel compared to fossil fuels. The focus of this study is to investigate methods to optimize ammonia combustion in typical grain drying conditions to enhance efficiency and sustainability.

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.

Ammonia offers a promising alternative to fossil fuels due to its potential to mitigate greenhouse gas emissions. However, challenges exist in its combustion process. Unlike natural gas or diesel, ammonia combustion is less efficient and produces nitrogen oxides (NOx) instead of CO2, contributing to air pollution. This study aims to develop a proof-of-concept prototype combustor tailored for grain drying, demonstrating ammonia combustion without harmful emissions. The proposed approach involves employing a heated catalytic bed alongside a high-pressure system. The catalytic bed decomposes ammonia into ammonia and hydrogen, aiding in more efficient combustion. Catalysts will be utilized to lower the activation energy required for combustion, enhancing efficiency. Additionally, high-pressure combustion will be explored to improve mixing and promote complete combustion. A unique flat flame burner will assess NOx emission reduction strategies. Insights gained will inform the design of an optimized grain dryer burner, maximizing efficiency while minimizing environmental impact. Overcoming challenges associated with ammonia combustion will facilitate its broader adoption as a sustainable fuel in agricultural settings, aligning with efforts to reduce carbon footprint.

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?

Ammonia has the potential to help Minnesota farms become more sustainable and reduce their environmental impact while also providing a cost-effective alternative for grain drying to traditional fossil fuels. By switching from fossil fuels to ammonia, Minnesota could save over 40 metric tons of carbon dioxide emissions each year. This significantly improves air quality in rural Minnesota and helps maintain the natural resources. Green ammonia produced from Minnesota's wind power benefits the environment by eliminating greenhouse gases like carbon dioxide and nitrous oxide, improving energy efficiency, and strengthening energy security for Minnesota farms.

Activities and Milestones

Activity 1: Development of a 100% ammonia-fueled high-pressure lab-scale burner with heated catalytic bed

Activity Budget: $110,000

Activity Description:
In this activity, a novel, reliable, and inexpensive lab-scale burner with a heated catalytic bed and high-pressure air and fuel stream supplies system will be developed for 100% ammonia combustion to achieve combustion efficiency ≥ 95%, leading to near-zero nitrous oxide emissions. Catalytic bed decomposes ammonia into ammonia and hydrogen, increasing the reactivity of the fuel/air mixture. On the other hand, High-pressure combustion improves mixing and promotes complete combustion, reducing NOx. The burner tip will be designed in such a way that it is easy to retrofit to a mobile grain drying unit.

We will perform a series of well-controlled, rigorous scientific experiments burning pure ammonia in a variety of experimental conditions and measuring the discharge products using gas chromatography. We will vary the input heating of the catalytic bed, catalyst types, inlet pressure of ammonia/air streams, and other parameters targeting various grain drying operating conditions. We will add grain drying specific compositions, humid air, additional dilution air, etc., and examine their effect on ammonia burning. The short-lived intermediate chemical species during ammonia combustion and radicals will also be measured for detailed chemical kinetics studies.

Activity Milestones:

Description	Approximate Completion Date
Develop the lab-scale ammonia burner to study 100% ammonia combustion	December 31, 2025
Complete testing of catalyst-assisted high-pressure ammonia combustion in a laboratory setting	February 28, 2026
Investigate the role of various catalyst parameters on ammonia burning	April 30, 2026
Activity 1 summary report	May 31, 2026

Activity 2: Optimize ammonia burner performance and process operating parameters to improve grain drying efficiency

Activity Budget: $70,000

Activity Description:
In this activity, our primary objective is to enhance the energy efficiency of grain drying by optimizing the 100% ammonia burner. We will explore various burner tip designs, including straight and swirl airflow configurations, to evaluate their impact on flame characteristics, burner efficiency, and emissions. By adjusting combustion parameters such as fuel-air ratio and residence time, we aim to fine-tune the burner performance for optimal grain drying.

An integral aspect of our approach involves the utilization of an iron-based catalyst known for its cost-effectiveness. We will compare this catalyst with palladium-based alternatives, considering factors such as catalyst structure, design, and heating rate to optimize its effectiveness in facilitating ammonia combustion under specified operating conditions. This optimization process will involve fine-tuning parameters to ensure efficient ammonia utilization while minimizing emissions.

Furthermore, we will design and fabricate various burner tips internally to ensure compatibility with existing grain dryer configurations. These burner tips will be engineered to facilitate stable and reliable combustion across the entire range

of planned testing scenarios. By integrating these optimized burner designs into existing grain dryers, we aim to enhance overall energy efficiency and sustainability in agricultural operations.

Activity Milestones:

Description	Approximate Completion Date
Test different catalyst performance on ammonia combustion	June 30, 2026
Complete a systemic parametric study of 100% ammonia combustion	October 31, 2026
Optimize burner parameters to enhance ammonia combustion	December 31, 2026
Activity 2 summary report	December 31, 2026

Activity 3: Create an easily retrofittable 100% ammonia burner tip for grain drying application

Activity Budget: $50,000

Activity Description:
In this activity, our focus is on adapting the hardware of a 100% ammonia burner tip for use in a portable grain drying system. We aim to achieve efficient combustion of ammonia by implementing suitable real-time control mechanisms to optimize performance and energy usage. An essential aspect of this endeavor is assessing the lifespan of the catalytic bed, which plays a critical role in the proposed technology's effectiveness.
We will conduct comprehensive evaluations of the burner's performance and emissions under various conditions, comparing its operation with and without our proposed technology to establish baseline measurements. These assessments will include direct comparisons with conventional natural gas or diesel operations to facilitate thorough cost-benefit analyses.

Moreover, we will provide detailed insights into the planned field testing of our ammonia-fueled grain drying system. This field-testing phase will serve as a crucial demonstration of the system's capabilities while identifying any potential concerns or obstacles that must be addressed before moving forward with commercialization efforts.

PI is actively leading the development and testing of this innovative 100% ammonia-burning technology, working closely with local farms in Minnesota, with the potential to attract widespread adoption among farmers, providing a sustainable solution for agricultural energy needs.

Activity Milestones:

Description	Approximate Completion Date
Integration and demonstration of 100% ammonia combustion technology completed	March 31, 2027
Complete preliminary evaluation for future field testing of the proposed technology in a local Minnesota	April 30, 2027
Provide detailed insights based on learnings from lab-scale ammonia burner testing	May 31, 2027
Activity 3 summary report	May 31, 2027

Activity 4: Reporting, IP and patent filing, results dissemination, and journal paper writing

Activity Budget: $20,000

Activity Description:
This phase of the project will focus on the final data analysis and report writing. In addition to meeting the deliverable requirements of the LCCMR Fund, the project team will prepare manuscripts for submission to peer-reviewed journals and will communicate the results of the project with the energy companies and waste management entities. Our final

goal is to demonstrate ammonia as a cost-effective, carbon-free alternative fuel that will power the off-road agricultural machinery, farms, and energy sector of Minnesota for decades to come.

Activity Milestones:

Description	Approximate Completion Date
File IP and patents before any public disclose of research results	March 31, 2027
Finished writing the first draft of the journal/conference article	March 31, 2027
Activity 4 summary report	April 30, 2027
Final project report	June 30, 2027

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Will Northrop	Mechanical Engineering, University of Minnesota	Prof. Will Northrop is a senior researcher and expert in the handling and utilization of ammonia. He will serve as a technical advisor to this project.	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?

Project results will be disseminated to Minnesota farms/agriculture, grain dryer manufacturers, and stakeholders through conferences, journal articles, reports, and direct communication, impacting strategic planning for primary agricultural machinery and grain dryer OEM stakeholders as they advance environmentally friendly grain drying and agricultural technologies. The USDA and Minnesota Department of Agriculture are dedicated to reducing agriculture's environmental impacts, offering potential funding avenues for further work and opportunities for partnerships with private agro-companies.

Project Manager and Organization Qualifications

Project Manager Name: Sayan Biswas

Job Title: Benjamin Mayhugh Assistant Professor

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

Prof. Sayan Biswas, Benjamin Mayhugh Assistant Professor of Mechanical Engineering, is an expert in clean energy, combustion, and novel laser-based sensing and diagnostics, will lead this project. PI Biswas has been working on ammonia combustion for the last several years. PI Biswas has extensive experience developing optical sensors for energy applications. His research has received support from the Department of Energy (DOE), Advanced Projects Research Agency-Energy (ARPA-E), NASA, Office of Naval Research (ONR), and several clean energy companies. He manages an annual research portfolio of $2.5M. Before joining the University of Minnesota in 2020, Dr. Biswas spent 3+ years at the Sandia National Laboratories and 5+ years at Purdue University, working on clean energy and developing advanced light/laser sensing systems. To date, PI Biswas has published 20+ journal articles, 40+ conference articles, 1 single-authored book, 6 book chapters, and holds 1 US patent. PI Biswas leads a highly diverse research group consisting of 6 PhD, 3 MS, and 8 UG students. His lab actively participates in educating the community about our energy future and in K-12 outreach activities, inspiring the next generation of scientists and engineers, and providing an open and equitable learning atmosphere for women, minorities, and indigenous students. Prof. Biswas serves on several technical and advisory committees, volunteering for his professional societies and local Minnesota-based organizations.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota, Twin Cities is a public land-grant research university in the Twin Cities of Minneapolis and Saint Paul, Minnesota, and one of the most comprehensive research universities in the nation. The University leadership acknowledges that the University of Minnesota Twin Cities is built within the traditional homelands of the Dakota people. It is the flagship institution of the University of Minnesota System and is organized into 19 colleges, schools, and other major academic units. The University advances Minnesota state and US society through new ideas, technologies, treatments, and cures, and continues to create and transfer technology to companies for the development of new products and services that benefit the public good and foster economic growth. The University's College of Science and

Engineering received $141.9 million in research funding in FY2015. The University of Minnesota College of Science and Engineering (CSE) ranks #4 in the country for the best bachelor's degree in engineering. In other rankings, CSE majors traditionally rank among the top 20.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Sayan Biswas		Principal Investigator			27.06%	0.12		$16,854
Post Doctoral Associate		Post Doctoral Associate			21.32%	1		$72,868
Research Assistant		Research Assistant			43.64%	1		$120,290
							Sub Total	**$210,012**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	The requested budget for materials and supplies includes miscellaneous consumables such as ammonia, catalysts, additives, and chemicals.	The requested budget for materials and supplies is essential to support various consumables crucial for the project's operations. These include miscellaneous items like ammonia, catalysts, additives, and chemicals necessary for conducting experiments and maintaining equipment. The estimated expenses, based on previous supply purchases, are allocated to cover specific categories of supplies. This breakdown includes $7,000 for catalysts, $2,000 for curing agents, reagents, stabilizers, and additional catalysts, and $1,000 for cleaning chemicals.					$15,000
							Sub Total	**$15,000**
Capital Expenditures								

		The estimated items include a flat flame burner, fabrication of a high-pressure flat flame burner in Year 1, modification of the flat flame burner system in Year 2, and fixture design for structural testing.	Based on the PI's prior experience and discussions with university machinists and technicians involved in constructing fixtures and test hardware, the estimated costs for various items have been determined. These include a flat flame burner priced at $8,000, fabrication of a high-pressure flat flame burner in Year 1 at the same cost, modification of the flat flame burner system in Year 2 amounting to $6,000, and fixture design for structural testing, which is budgeted at $2,000.	X				$8,000
		Ammonia burner, a novel design to burn using 100% ammonia	Ammonia burner to study high-efficiency or ammonia combustion and NOx emissions using high-fidelity laser measurements	X				$8,000
							Sub Total	**$16,000**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	a) Travelling to a MN farm to understand the cost-benefit and ammonia storage pressure, etc., once/twice during the project lifetime, b) One trip per year for PI, postdoctoral researcher, and the graduate student to a relevant conference	Attend conference for knowledge dissemination and attract potential customers/end-users					$5,988
							Sub Total	**$5,988**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								

							Sub Total	**-**
Other Expenses								
		Scientific Services	The budget covers use-fees pre- and post-combustion plasma surface characterization and plasma geometry observation at the Minnesota Nano Center and CharFac, along with pre- and post-combustion gas composition measurement. These expenses are estimated based on previous user fees.					$3,000
							Sub Total	**$3,000**
							Grand Total	**$250,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		The estimated items include a flat flame burner, fabrication of a high-pressure flat flame burner in Year 1, modification of the flat flame burner system in Year 2, and fixture design for structural testing.	These investments are vital for advancing research in combustion science within Minnesota, fostering local innovation and contributing to the state's leadership in sustainable energy technologies. **Additional Explanation :** After the project concludes, the flat flame burner system will continue to be utilized for ongoing research endeavors, providing valuable insights into combustion processes and related studies. Additionally, the modified burner system will be adapted for new experiments or repurposed for similar research projects, ensuring its continued utility beyond the current project scope. The fixture designed for structural testing can also be repurposed for future experiments or shared with other research teams, maximizing its use and contributing to broader scientific advancements.
Capital Expenditures		Ammonia burner, a novel design to burn using 100% ammonia	Developing a novel ammonia burner capable of running on 100% ammonia is crucial for reducing reliance on fossil fuels and mitigating greenhouse gas emissions. Despite its challenges, our attempt to create such a burner is essential in advancing sustainable energy solutions. By achieving complete combustion of ammonia, we demonstrate its viability as a cleaner fuel source, aligning with global efforts to transition towards renewable energy and combat climate change. **Additional Explanation :** The development of an efficient ammonia burner is pivotal for the success of this project, as it serves as the cornerstone of our efforts to utilize ammonia as a sustainable fuel source. This burner will not just be used throughout this project but also for many more years to come.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	unrecovered F&A calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$109,184
			Non State Sub Total	**$109,184**
			Funds Total	**$109,184**

Total Project Cost: $359,184

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 8e912626-97b.pdf

Alternate Text for Visual Component

The visual highlights the benefits of utilizing ammonia as a fuel source, showcasing a portable grain dryer powered by pure ammonia, along with our approach and design for achieving complete combustion of 100% ammonia....

Supplemental Attachments

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

Title	File
UMN SPA Letter of Support	5f9bda66-232.pdf
Ammonia corn drying	89179c08-1ff.pdf
Grain drying using ammonia	34d5fa63-f0b.pdf
Ammonia for domestic application	18447dc5-fbe.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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:

Alex Sullivan, U of MN