Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 176-E**

Development of Clean Energy Storage Systems for Farms

Category: E. Air Quality, Climate Change, and Renewable Energy

Sub-Category:

Total Project Budget: $ 994,224

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

Energy storage systems for farms will be developed using wind-generated ammonia. Novel ammonia fuel systems will be tested in a farm grain dryer and engine generator displacing fossil fuels.

Name: William Northrop

Sponsoring Organization: U of MN - WROC

Title: Director, Renewable Energy Program

Department: Sponsored Projects Administration

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Picture a clean energy storage system with ammonia used for fertilizer and fuel. A pie chart shows 90% of fossil energy used for corn production displaced with wind-generated ammonia.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Development of Clean Energy Storage Systems for Farms

I. PROJECT STATEMENT

We propose to develop and test a clean energy storage system for farms using anhydrous ammonia produced from wind energy. Currently, the West Central Research and Outreach Center (WCROC) is operating a pilot plant that uses wind energy to drive an ammonia production process. In this project, ammonia will be tested as fuel for grain drying and for electric generators. Successful development of this farm energy storage system will have a dramatic impact on reducing fossil energy consumption and greenhouse gas emissions in grain, feed, meat, milk, and biofuel production.

According to the MPCA report to the Minnesota Legislature, *Greenhouse gas Emissions: 1990-2014*, the agriculture sector in Minnesota ranks 3rd next to electric generation and transportation in greenhouse gas emissions with a total of approximately 30 million tons of CO_2-equivalents. In studying the energy and carbon footprint of crop production at the West Central Research and Outreach Center, results indicated that grain drying made up 41.6% of the fossil energy attributed to grain production. Nitrogen fertilizer was the second highest fossil energy consumer at 36.4% while tractor field work was at 13.9% and transportation at 1.18% (Tallaksen et al, 2016). The conventional fuels used in these processes include combusting propane and natural gas for grain drying, natural gas steam methane reforming for nitrogen fertilizer production, and diesel fuel for field work and transportation. We currently are testing the near-zero carbon ammonia as nitrogen fertilizer and for displacing diesel fuel in tractors. If this same ammonia can displace propane and natural gas for grain drying and power generation, *we have a system that can eliminate over 90% of the energy and carbon footprint of corn production!* This impact has a significant ripple affect substantially lowering the energy and carbon footprint of meat and dairy products and ethanol production.

The ability to store wind and solar energy is key to an efficient and effective energy system especially for farms. In general, batteries are considered to be the most logical source of energy storage. However, batteries are costly and can only store energy for short durations. The US Dept. of Energy indicates that using ammonia for energy storage is much more cost effective than batteries and other forms of storage (Soloveichik, 2016). Also, if ammonia is produced from wind and solar, it can be stored and used seasonally. It can be used for nitrogen fertilizer and tractor fuel in the spring and for powering irrigation and backup generators in the summer. In fall, it can be used for grain drying, fertilizer, and tractor and transport fuel. In winter, ammonia can fuel furnaces and for electrical power generation needs. Therefore, wind and solar energy paired with ammonia production, can provide a comprehensive, dynamic, and year-round clean energy system for farms.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop and test catalytic ammonia decomposition on a laboratory combustion system
ENRTF BUDGET: $117,000

A combustion system using a catalytic reformer will be developed and tested in partnership between the U of MN Murphy Engine Research Lab (MERL) and U of MN Duluth. Testing will include ignition, flame and heat control, emissions, fuel mixing, heat rates, residence times, and catalytic, thermal, and combustion efficiency.

Outcome	Completion Date
1. Design review completed for an ammonia-fueled combustion system.	*1/1/2020*
2. Fabrication of an ammonia-fueled combustion system completed.	*6/30/2020*
3. Ammonia-fueled combustion system tested and refined.	*1/1/2021*

Activity 2: Field testing of a catalytic ammonia decomposition fuel system on a farm-scale grain dryer
ENRTF BUDGET: $282,797

A prototype catalytic reformer and combustion system will be developed at the UMN Duluth and then retrofitted to a grain dryer for field testing at the WCROC research farm. Ammonia produced using wind energy will fuel the prototype combustion system. The system will first be tested in an empty grain dryer. Once the system has been fully commissioned, several batches of corn grain will be dried. In addition to flame stability and efficiency characteristics, grain residence time and moisture levels into and out of the grain dryer will be measured.

Outcome	Completion Date
1. Design and fabricate a prototype ammonia-fueled combustion system for a grain dryer.	*6/30/2021*
2. Prototype ammonia combustion system installed and commissioned on a grain dryer.	*9/30/2021*
3. Grain dried and field-testing completed within the ammonia-fueled grain dryer.	*12/31/2021*
4. Perform a life cycle assessment to determine impact on GHG emissions.	*6/30/2022*

Activity 3: A catalytic reformer will be developed and tested on a compressed gas engine genset.
ENRTF BUDGET: $594,447

A catalytic ammonia decomposition fuel system for a compressed gas engine will be designed, fabricated, and tested at the MERL lab. Once lab testing is complete, the system will be installed and tested on compressed gas engine genset at the WCROC.

Outcome	Completion Date
1. Design review completed for an ammonia-fueled engine genset.	*1/1/2020*
2. Fabricate reactor and test an ammonia catalytic composition system on an engine.	*1/31/2021*
3. Field-test an ammonia-fueled compressed gas engine genset at the WCROC.	*4/30/2022*
4. Perform a life cycle assessment to determine impact on GHG emissions.	*6/30/2022*

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Dr. Will Northrop	Professor / Director of MERL	UMN Dept of Mech Eng.	PI
Dr. Alison Hoxie	Associate Professor	UM-Duluth Dept of Mech & Industrial Eng.	Co-PI
Eric Buchanan	Renewable Energy Scientist	U of MN WCROC	Co-PI

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
NA			

IV. LONG-TERM- IMPLEMENTATION AND FUNDING: The main goal of this project is to show that ammonia can be effectively used within a farm energy storage system. The long-term goal is to develop commercially viable near zero carbon technologies that can be implemented on farms.

V. TIME LINE REQUIREMENTS: The project is three years beginning July 1, 2019 and ending June 30, 2022.

VI. SEE ADDITIONAL PROPOSAL COMPONENTS*: (Categories C., D., and E. are intentionally deleted).*
A. Proposal Budget Spreadsheet, B. Visual Map, F. Project Manager Qualifications and Organization Description, G. Resolution , H. Certified Audit or 990 Tax Information

2019 Proposal Budget Spreadsheet

Project Title: Development of Clean Energy Storage Systems for Farms

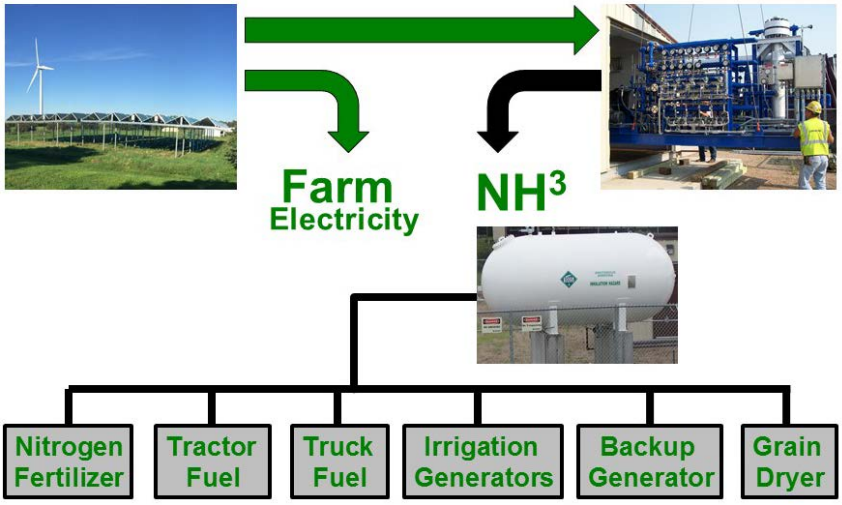
IV. TOTAL ENRTF REQUEST BUDGET *3* **years**

BUDGET ITEM	AMOUNT
Personnel: Dr. Will Northrop, PI, $50,324 (1 month summer salary / yr, Yrs 1-3, 33.5% fringe). Dr. Alison Hoxie, Co-PI, $20,000 (1 month summer salary / year, Yrs 1-2, 33.5% fringe). Graduate student for NH3 engine, $223,997 (Yrs 1-3, 15% fringe, 50% RA). Graduate student for NH3 combustion system, $80,000 total (Yrs 1-2 plus summer salary, 15% fringe). Darrick Zarling, MERL research coordinator, $126,382 (20 wks / yr, Yrs 1-3, 33.5% fringe). Dr. Joel Tallaksen, LCA scientist, $89,703 (.5 FTE Yrs 2-3, 33.5% fringe, 2.25% COLA). Eric Buchanan, WCROC research engineer, $64,776 (.4 FTE Yrs 2-3, 33.5% fringe, 2.25% COLA), Cory Marquart, WCROC research scientist, $62,927 (.5 FTE, Yrs 2-3, 27.2% fringe, 2.25% COLA). WCROC farm tech, $37,321 (.3 FTE, Yrs 2-3, 27.2% fringe, 2.25% COLA). MERL undergrad intern, $17,804 (3 summers, 0% fringe). WCROC undergrad intern $6,000 (1 summer, 0% fringe).	$ 779,234
Professional/Technical/Service Contracts: Est. $20,000 for an engineering firm to conduct a Process Hazard Assessment of the combustion system and engine genset at WCROC. $9,000 for an electrician to unhook and hook up the engine genset at WCROC for delivery to MERL and then return. $9,000 for a grain dryer mechanic to install new burner and components. $5,000 for a hydrogen and ammonia safety trainer ($500 ea, 10 people). $5,000 for emissions calibration at MERL.	$ 48,000
Equipment/Tools/Supplies: $22,000 for grain dryer components at WCROC (two modified burners, regulators, gas piping, controls, wiring and mounting brackets). $9,400 for engine genset components and interconnection supplies at WCROC. $30,000 for lab system plumbing, electrical supplies, test cell parts, and other consumables at MERL (est. $10,000 /yr). $20,000 for Parts for decomposition system(s) including metal parts, fittings, control hardware, wiring, and catalysts. $16,000 for lab consumables at UMD. $16,000 for catalyst used in combustin system at UMD and WCROC, $18,000 for renewabl ammonia production components and supplies at WCROC ($9k/yr). $10,000 for sensors, meters, and vented container at WCROC.	$ 141,400
Travel: In-state travel for project team. Amount includes $7,380 each (x2) for Northrup and Hoxie travel to Morris (3 trips / year, 330 miles per trip, 2 people, two nights, 3 meals / trip) and $3,450 for Reese travel to Minneapolis and Duluth (2 trips / year, 330 miles per trip, one night, 3 meals/trip), and $1,000 for truck and trailer WCROC genset delivery to and from MERL.	$ 19,210
Additional Budget Items: $4,000 for crane service to load / unload genset at WCROC. $2,400 for industrial heater lease (reactive load for genset testing).	$ 6,400
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 994,244

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	$ -	*NA*
Other State $ To Be Applied To Project During Project Period:	$ -	*NA*
In-kind Services To Be Applied To Project During Project Period: Unrecovered F&A	$ 493,928	*Pending*
Past and Current ENRTF Appropriation: Appropriations related to this project includes: 1. A 2006 ENRTF project to produce hydrogen from wind energy ($800k). 2. A 2015 ENRTF project to research new renewable nitrogen fertilizer production technologies ($1 million - in progress), and 3. A 2016 ENRTF project 'Hydrogen fuel from Wind-Produced Ammonia" to displace diesel fuel in tractors ($250K - in progress).	$ 2,050,000	Secured
Other Funding History: $2.95 million was provided by the University and State to complete the renewable hydrogen and ammonia pilot plant at WCROC. $500k and $400k was provided by UMN MnDRIVE and UMN IREE respectively to refine ammonia production technologies, develop policy, and evaluate economics. $180K was provided by Mn Corn to evaluate a novel production technology and evaluate initial economics. $2.9 million was awarded by the US Dept of Energy ARPA-E REFUEL program to develop and test a pilot-scale production unit of a novel ammonia production technology developed within the U (in progress). Funding is also provided by the	$ 6,930,000	*Secured*

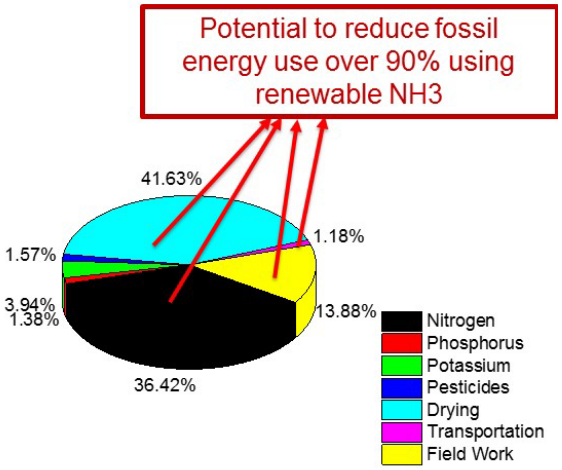
Farm Energy Storage System Concept



Conventional Corn Production

Fossil Energy Use

- Roughly 1.6 MJ per kg corn
- Fuel for tillage is a fairly minor component
- Grain drying is the largest single energy consumer
- Nitrogen fertilizers are also very high



Tallaksen, 2016

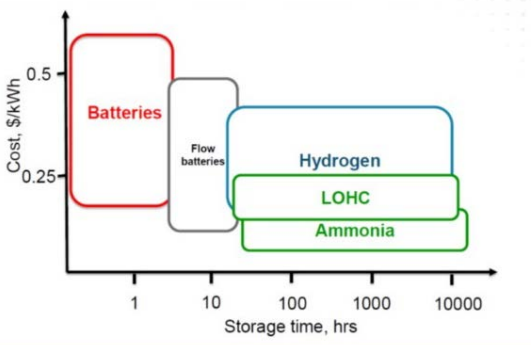
Renewable ammonia for grain dryers and furnaces:

CH4/NH3/Air, 300C (Kumar et al, 2010)

Integrated Reactor Manifold

Displacing Propane and LNG in Grain Dryers

Levelized cost of energy storage



arpa·e

G. Soloveichik, US Dept. of Energy, 2016

F. Project Manager Qualifications and Organizational Description

Will Northrop, Principle Investigator and Project Manager: Will Northrop, Assistant Professor, University of Minnesota-Twin Cities Department of Mechanical Engineering is the Co-Director of the TE Murphy Engine Research Laboratory and has extensive experience in experimental engine research in both academia and industry including work in dual-fuel combustion modes. He also is experienced in catalytic fuel reforming and hydrogen production for fuel cells and is named on three patents pertaining to thermally integrated catalytic substrates.

The University has recently commissioned a new $6M state-of-the-art engine research facility at the T.E. Murphy Engine Research Laboratory. The lab is equipped with three AC regenerative dynamometers and new emissions analysis capability including a perfectly suited to achieve the technical objectives set out in the proposed research. The lab also includes suitable facilities for catalyst testing and analysis of products using gas chromatography and Fourier Transform Infra-Red analysis.

In addition to the Engine Research Lab, research will occur at the West Central Research and Outreach Center (WCROC) which has been recognized world-wide for its leadership in researching and demonstrating the production of hydrogen and anhydrous ammonia from wind energy. The Renewable Hydrogen and Ammonia Pilot Plant was the first in the world. The pilot plant is located at the WCROC on the rolling prairies and fields of western Minnesota. The WCROC is a century-old agricultural experiment station consisting of approximately 1,100 acres of pasture and farmland, administration office complex, grain and livestock facilities, and supporting research facilities. The WCROC also houses the regional extension office for western Minnesota. In addition to the Renewable Hydrogen and Ammonia Pilot Plant, renewable energy systems located at the WCROC include a 1.65 MW Vestas V-82 wind turbine, two 10 kW wind turbines, an evacuated tube solar thermal system, two flat-plate solar thermal systems, and four solar PV systems totaling 101 kW. Prior to the start of this project, two 10 kW wind turbines and 54 kW of ground mount solar PV will be installed on the research farm. The renewable energy staff also operate a 60 kW hydrogen engine genset and two Toro Workman utility vehicles that are powered by hydrogen fuel cells. The genset and utility vehicles are fueled from the hydrogen produced at the pilot plant. The Renewable Hydrogen and Ammonia Pilot Plant is equipped with sensors and meters in order to collect the desired input and output data for research protocols as well as controls necessary for automated control of production processes. This automation also includes electronic notification of safety issues or equipment failure and plant shutdown. As a research farm, staff have experience applying ammonia to fields, operating grain dryers, and running engine gensets. Annually, over three hundred acres of corn is planted and harvested. The corn is then dried on-site in the WCROC grain facilities. This applied research setting provides an excellent venue to address real world issues and help solve grand challenges. In this case, data collected at the research farm has identified grain drying and nitrogen fertilizer use as having the largest impact on the energy and carbon footprint of corn production. We are now requesting funds to develop practical solutions.