Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID:** 101-E

Renewable and Sustainable Fertilizers Produced Locally

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

Total Project Budget: $ 1,620,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

New technologies in Minnesota will enable renewable and sustainable, zero-carbon-footprint ammonia for fertilizers to be produced at the local level close to farms - in Minnesota and around the world.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township: Morris especially

Alternate Text for Visual:

Conventional fertilizer is now produced in massive facilities, from natural gas, typically located on a natural gas pipeline, with extensive transportation networks required to deliver the fertilizer; this leads to high carbon footprint and to price dependence on global influences, with intermittent price spikes. In contrast, new technology developed in Minnesota can enable farms, coops, or counties to make ammonia-based fertilizer at the local level - using renewable energy, air and water - with no carbon footprint, and with no dependence on extensive transportation infrastructure. Integration of local fertilizer production with hydrochar can also reduce runoff nitrogen and phosphorus.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL

PROJECT TITLE: Renewable and Sustainable Fertilizers Produced Locally

I. PROJECT STATEMENT

Conventional production of nitrogen fertilizer has many environmental drawbacks - using natural gas as reactant, emitting greenhouse gases, relying on energy-intensive chemical plants and distribution network. We are developing new technologies to improve the environment - enabling production with zero carbon footprint, using just water and air as reactants, using wind or solar energy, and using small inexpensive facilities that can be near the farm. The United Nations projects world population of 10.9 billion by 2050, and feeding the world only using conventional fertilizer production and distribution would have disastrous environmental impact. Environmentally benign fertilizer technology will reduce the carbon footprint of agriculture in Minnesota and around the world. Moreover, farms benefit from locally produce fertilizer to supplement conventional supplies when they are pinched by distribution or price constraints.

We have already demonstrated the promise of farm-scale environmentally-benign ammonia synthesis in a unique UMN facility - the Renewable Hydrogen and Ammonia Pilot Plant facility at WCROC in Morris - using wind energy, getting reactant nitrogen from air and hydrogen from water, nourishing 300 acres of cornfield. As elegant as this process is, though, economies of scale and cost of production remain serious limitations for practical widespred use of the technology. First, a state-of-the-art reactor achieves only partial reaction conversion, requiring capital- and energy-intensive separation and recycle of the unreacted reactant mixture; the engineering of this is feasible only with economy of scale in massive ammonia plants. The second key limitation is the high pressure typically required of the state-of-the-art chemistry, unless novel chemistry is employee.

We will bring new technologies from our labs to the demonstration scale to reduce the capital and energy requirements, and we will provide engineering and economic models to design and implement local, environmentally-benign fertilizer production. Activity 1 will lower capital cost by eliminating the first key engineering constraint - the need to perform recycle operations. Activity 2 will use novel plasma chemistry to eliminate the need for high pressure. Activity 3 will show how the potential to improve the safety and transport ease of the fertilizer product, and reduce the environmental impact of nitrogen runoff from fields. Activity 4 will bring these together, integrating demonstration results of these three cutting edge technologies with rigorous economic analysis to project true sustainability and environmental impact, using state of the art engineering and economic modeling as well as analysis of how policy trends will affect these.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: ***Improve efficiency for absorbent-enhanced ammonia synthesis*** **Budget: $738,000**

The first cutting edge technology is the use of an absorbent material in the reactor to remove ammonia from teh catalyst, increasing the conversion enough to eliminate the need for recycle. The detailed engineering issues are not trivial, but we are nearing readiness to implement and test the technology (so far only in the lab) at the WCROC demonstration reactor. Since this is moving to demonstration scale, this activity is the most costly - engaging 4 of the senior personnel, 2 research assistants, and the services of a professional engineering design firm for reliable and safe implementation at the demonstration scale.

Outcome	Completion Date
1. Scale-up principles from lab to wind-farm scale absorbent-enhanced reactor	*End of year 1*
2. Design of absorbent enhancement for ammonia reactor in Morris MN	*End of year 2*
3. Implementation of absorbent enhanced reactor in Morris MN	*End of year 3*

Activity 2: ***Low pressure ammonia synthesis using non-thermal-plasma*** **Budget: $226,000**

The second technology uses a catalytic non-thermal plasma reactor, which uses novel chemistry to produce ammonia at much lower temperatures and pressures than with the typical catalytic process. If this can be done at sufficient rate, and low enough energy input, this can further reduce the capital costs and better enable inexpensive local production.

Outcome	Completion Date
1. Develop and improve the catalytic NTP Processes	*End of year 1*

2. Develop, test and optimize the catalytic NTP process and the small pilot scale system	*End of year 2.5*
3. Evaluate and demonstrate the catalytic NTP process and system	*End of year 3*

Activity 3: *Capture of ammonia with hydrochar for field application* **Budget: $129,000**

The third technology uses of hydrochar, a material derived from biomass that acts as a soil amendment, to facilitate field distribution of ammonia, reducing fertilizer runoff. This technology has been developed so far by researchers in the Biotechnology Institute; we will explore how much it can further enhance the viability of local ammonia production and distribution.

Outcome	Completion Date
1. Make engineered-hydrochars from various biomass sources and activating metals and evaluate nitrogen sorption/desorption properties in laboratory.	*End of year 1*
2. Design, construct and test a laboratory scale engineered -hydrochar filter for use in removal of dissolved nitrogen and phosphorous.	*End of year 2*
3. Determine efficacy of hydrochars as soil amendments, integrating with ammonia	*End of year 2*

Activity 4: *Integration, modeling, planning for various economic and policy scenarios* **Budget: $527,000**

Research at the Morris facility and with the three cutting-edge technologies above will be integrated into engineering modeling and economic analysis to help design optimal solutions responsive to a variety of business models and scenarios. Policy, economic, and business model options will be examined that affect the interaction of distributed ammonia producing sites with the electric grid, that relate to ammonia pollution that may affect distributed ammonia fertilizer production or create incentives for innovation in ammonia application methods, and that affect how distributed ammonia production may relate to distributed hydrogen production. (e.g., with increasing fertilizer value, fluctuating energy values, distance from infrastructure, policy incentives and regulations in place). This multidisciplinary technology will involve a wide variety of expertise.

Outcome	Completion Date
1. Model development for different technologies	*End of year 1*
2. Conduct techno-economic evaluation and feasibility assessment	*End of year 2*
3. Formulate a development and commercialization strategy	*End of year 3*

III. PROJECT STRATEGY

A. Project Team/Partners

Our multidisciplinary team (further described in Attachment 6) has grown through previous environmental grants and the current MNDrive program at UMN-TC. Alon McCormick, Chemical Eng. and Materials Science (CEMS) - (612) 625-1822 mccormic@umn.edu; Michael Reese, UMN WCROC; Ed Cussler, CEMS; Prodromos Daoutidis, CEMS; Steve Kelley, UMN Humphrey School of Public Affairs; Roger Ruan, Bioproducts and Biosystems Engineering; Lanny Schmidt, CEMS; Douglas Tiffany, UMN Extension; Kenneth Valentas, UMN Biotechnology Institute; Cecil Massie, AMEC - Power and Process Americas Division, Minneapolis

B. Project Impact and Long-Term Strategy

The proposed work is aligned with previous environmental grant work (the origin of this team) and the UMN WCROC strategic plan to reduce fossil energy dependence and carbon footprint in production agriculture. The ultimate goal is demonstration for economic and engineering modeling allowing commercial implementation. Its environmental benefits in agriculture can be huge, and the economic potential for green business development with this technology in Minnesota is substantial.

C. Timeline Requirements

The proposed 3-year project July 2015 - June 2018 is planned to bring cutting edge technologies to demonstration, allowing prospects for large-scale environmental impact and commercialization.

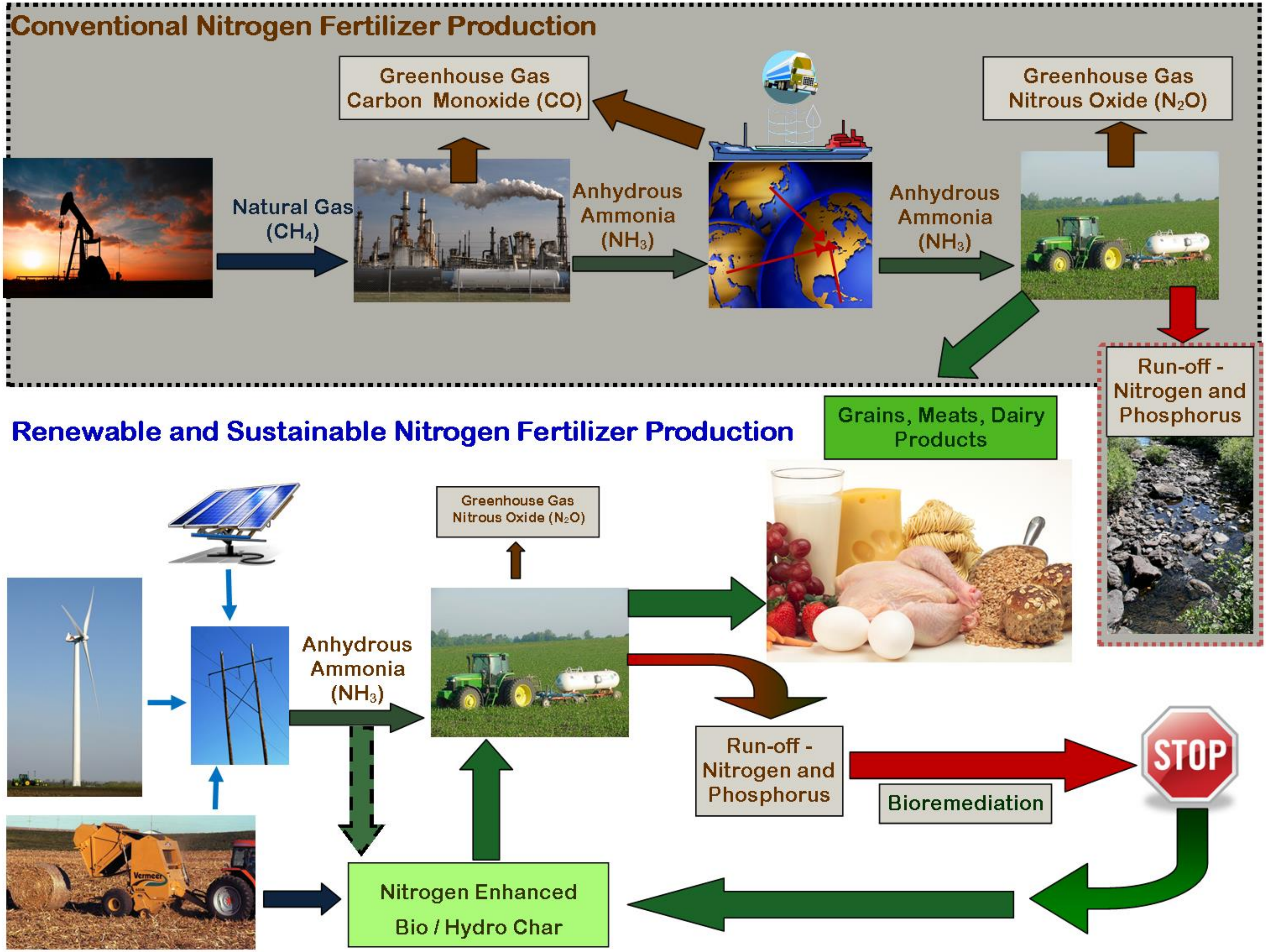
Project Title: Renewable and Sustainable Fertilizers Produced Locally

IV. TOTAL ENRTF REQUEST BUDGET - 3 years

BUDGET ITEM	3 year TOTAL
Personnel:	
SENIOR PERSONNEL - ca. $10K/yr budgeted for each PI over 3 years toward salary and fringe; covers 4-20% of each PI's time, depending on UMN appointment; 33.6 % fringe rate	
PI McCormick at .05 FTE	$ 30,000
PI Reese at .11 FTE	$ 30,000
PI Daoutidis at .05 FTE	$ 30,000
PI Schmidt at .04 FTE	$ 30,000
PI Cussler at .09 FTE	$ 30,000
PI Kelley at .11 FTE	$ 30,000
PI Ruan at .06 FTE	$ 30,000
PI Tiffany at .09 FTE	$ 30,000
PI Valentas at .14 FTE	$ 30,000
RESEARCH ASSISTANTS - 5.2 FTE averaged over 3 years. Ca. $60K/yr budgeted for salary and fringe for each research assistant, who may be graduate student, postdoctoral associate, or technical staff. 4.5 assistants working full 3 years: 2 assistants in Activity 1 (with Reese,McCormick, Cussler, and Schmidt), 1 assistant in Activity 2 (with Ruan), 0.5 assistant in Activity 3 (with Valentas), and 1 assistant in Activity 4 (with Daoutidis) 1 additional assistant working 2 years in Activity 4 (Years 2&3 with Tiffany). Depending on type of appointment, fringe rates of 16-34% (plus tuition benefit for grad students).	$ 930,000
TOTAL PERSONNEL	**$ 1,200,000**
Contracts:	
AMEC Engineering (or equivalent firm) - Professional Services for Demonstration Reactor at WCROC Modeling, Pre-design, Design, Commissioning, Safety and Control Engineering	$ 330,000
TOTAL CONTRACTS	**$ 330,000**
Equipment/Tools/Supplies:	
Experimental supplies for research assistants Chemicals, lab analysis, safety and laboratory supplies about $3000/year budgeted from each FTE research assistant	$ 54,000
TOTAL EQUIPMENT AND SUPPLIES	**$ 54,000**
Travel:	
In-state travel between Morris and Twin Cities for full-day research collaboration Monthly visits, ca. $300 for 2 person overnight Morris to TC, ca. $100/person for TC to Morris	$ 9,000
TOTAL TRAVEL	**$ 9,000**
Additional Budget Items:	
Costs for reporting, grant administration, conference organization, outreach, and publication Ca. $1000/yr for each co-PI	$ 27,000
TOTAL ADDITIONAL BUDGET ITEMS	**$ 27,000**
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	**$ 1,620,000**

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status July 2015
Other Non-State $ To Be Applied To Project During Project Period: **UMN MNDrive project, year 2**	$ 200,000	pending
Other State $ To Be Applied To Project During Project Period:	NA	NA


Conventional Nitrogen Fertilizer Production
Greenhouse Gas
Carbon Monoxide (CO)
Greenhouse Gas
Nitrous Oxide (N_2O)
Natural Gas
(CH_4)
Anhydrous
Ammonia
(NH_3)
Anhydrous
Ammonia
(NH_3)
Run-off -
Nitrogen and
Phosphorus
Renewable and Sustainable Nitrogen Fertilizer Production
Grains, Meats, Dairy
Products
Greenhouse Gas
Nitrous Oxide (N_2O)
Anhydrous
Ammonia
(NH_3)
Run-off -
Nitrogen and
Phosphorus
Bioremediation
STOP
Nitrogen Enhanced
Bio / Hydro Char

Attachment 6 - Project Manager Qualifications and Organization Description

Renewable and Sustainable Fertilizers Produced Locally

Alon McCormick is Professor in Department of Chemical Engineering and Material Science (College of Science and Engineering), one of the most highly ranked departments at the University of Minnesota - Twin Cities. McCormick has previously served as PI on an IREE funded project with co-PI's Reese, Cussler, Ruan and Tiffany on a project that has paved the way to the technologies to be implemented in this proposed work. Over 25 years McCormick has taught and guided the research of graduate students, undergraduates, and postdoctoral associates and, with them and colleagues, has published over 170 scientific papers.

McCormick will serve as project manager in close collaboration with Michael Reese, keeping the focus of the project on current and future implementation at the renewable ammonia facility in Morris. For the past twelve years, Reese has been the Renewable Energy Director at the West Central Research and Outreach Center – Morris. He has overseen the development of the renewable energy program at Morris and has participated as Project Manager on over $14 million of research and demonstration projects including wind energy, biomass gasification, renewable hydrogen and ammonia, and solar energy systems.

McCormick will also draw on the expertise of colleagues in his department: Ed Cussler, Lanny Schmidt (Regents Professor), and Prodromos Daoutidis , who are widely recognized as international leaders in the fields (respectively) of chemical transport and separations; of reaction kinetics and equilibrium and reactor engineering; and of process optimizaiton, control and systems engineering of renewable and sustainable systems. McCormick will also team with Roger Ruan (Bioproducts and Biobased Engineering, in the College of Food, Agriculture, and Natural Resource Sciences), whose career includes key contributions to renewable systems engineering; with Kenneth Valentas, Adjunct Professor, former Director of the BioTechnology Institute (College of Biological Sciences), and former Senior Vice President of Engineering at Pillsbury, recognized expert in process engineering focusing on renewable energy with particular emphasis on thermochemical processing and hydrothermal carbonization (HTC) of biomass; and Steve Kelley, Senior Fellow, Humphrey School of Public Affairs and Douglas Tiffany, Assistant Extension Professor, Minnesota Extension Service (EFANS), nationally recognized for policy and economic analysis of renewable systems. He will also enjoy useful collaboration with Cecil Massie, Senior Process Engineer, AMEC - Power and Process Americas Division, Minneapolis, with experience in a wide variety of renewable designs and plan startups.

The primary organization is the University of Minnesota-Twin Cities with researchers from the West Central Research and Outreach Center (WCROC), Chemical Engineering and Materials Science Department, the Biotechnology Institute, the Bioproducts and Bioengineering department, and the Humphrey Institute. Experiments on new technologies will be performed in several colleges in the Twin Cities, but the WCROC, located near Morris, will serve as the primary project location for implementation of the new technologies. The WCROC is a century-old 1,100-acre agricultural experiment station that focuses on applied research. It has several relevant program areas including renewable energy, swine and dairy production, and conventional and organic crop production. The Renewable Hydrogen and Ammonia Pilot Plan facility at WCROC constitutes one of the most innovative experimental assets of the state in the field of sustainable nitrogen fertilizer produced from renewable wind energy.