Environment and Natural Resources Trust Fund (ENRTF) M.L. 2015 Work Plan

Date of Report: May 20, 2015

Date of Next Status Update Report: January 1, 2016

Date of Work Plan Approval:

Project Completion Date: June 30, 2018

Does this submission include an amendment request? _No_

PROJECT TITLE: Renewable and Sustainable Fertilizers Produced Locally

Project Manager: Alon McCormick

Organization: University of Minnesota

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Location: Statewide, especially Morris

Total ENRTF Project Budget: $1,000,000	**ENRTF Appropriation:**	**$1,000,000**
	Amount Spent:	**$0**
	Balance:	**$1,000,000**

Legal Citation: M.L. 2015, Chp. 76, Sec. 2, Subd. 07a

Appropriation Language:
$1,000,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota for the Morris West Central Research and Outreach Center and Twin Cities Campus to develop and demonstrate new technologies aimed at enabling renewable and sustainable production of ammonia for fertilizer in a localized manner. This appropriation is subject to the requirements in Minnesota Statutes, section 116P.10. This appropriation is available until June 30, 2018, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Renewable and Sustainable Fertilizers Produced Locally

II. PROJECT STATEMENT:

Humankind is faced with a grand challenge - to feed the world while sustaining the environment. 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 of fertilizer with zero carbon footprint, using only water and air as reactants, using wind or solar energy, and using small inexpensive facilities that can be near the farm.

The ultimate goal is to make renewable and sustainable fertilizer technologies realistic for Minnesota companies and farmers. We will bring new technologies from our labs to the demonstration scale to reduce the capital and energy requirements for sustainable fertilizer production, 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 expensive energy-intensive high pressure recycle operations. Activity 2 will use novel plasma chemistry to eliminate the need for high pressure. Activity 3 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. Activity 4 will explore prospects for developing time-release ammonia.

The United Nations projects world population of 10.9 billion by 2050, and feeding the world only using conventional fertilizer production and distribution will have disastrous environmental impact. Environmentally benign fertilizer technology will reduce the carbon footprint of agriculture - both 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.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of January 1, 2016:

Project Status as of July 1, 2016:

Project Status as of January 1, 2017:

Project Status as of July 1, 2017:

Project Status as of January 1, 2018:

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: ***Improve efficiency for absorbent-enhanced ammonia synthesis***

Description:

In the last decade 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. But as elegant as this process is, economies of scale and cost of production remain serious limitations for practical widespread use of the technology.

First, the existing conventional reactor achieves only partial conversion of raw materials, 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. When the nitrogen and hydrogen are combined over the catalyst at high pressure and temperature, the reaction is still incomplete: the unreacted gases must still be separated and recycled. While such a process will work, the need for the recycle means that the process is just a scaled down version of the current one. Because the economies of scale of the large plants are lost, the locally made ammonia will be more expensive. We will work toward ways to reduce this expense, eliminating the need for conventional separation and recycle by using high temperature absorption of the ammonia.

The second key limitation is the high pressure typically required of the state-of-the-art process. We intend to perform the separation of ammonia sufficiently well that lower pressures can provide adequate reaction rate. Our analysis of the catalyzed kinetics suggests that if we can remove ammonia efficiently enough with the absorbent, the suppression of equilibrium limitations may be sufficient to allow us to get respectable rates at much lower pressure. Rather than the 80 atm typical in current state-of-the-art reactors, we need to reduce the pressure by an order of magnitude and still achieve acceptable rates. This would be a breakthrough, reducing hazard and cost enormously. We will endeavor to partner with companies (preferably MN companies) to realize this implementation and also to enable practical realization well beyond the Morris pilot plant.

We will improve the process in three ways.

Task 1: Better absorption
We want to absorb the ammonia more quickly and at lower pressure. Making the absorption faster will need more absorbent ground into much smaller particles following well-established methods. Running at low pressure should be possible according to published data for ammonia synthesis. Doing so will make the process equipment cheaper and safer. We aim to complete this improvement in the first year, boosted by the preceding work funded by the University of Minnesota MNDrive effort.

Task 2: Reduce need for temperature control
Our second improvement is to run both reaction and absorption at the same high temperature. At present, the adsorption is carried out at lower temperature. We estimate learning how to absorb hotter will take a year, and again will reduce the cost and complexity of the equipment. Along with that effort, we will work with stakeholders to find a partner to design an implementation with the Morris pilot plant facility.

Task 3: Simplify reactor/absorber
Our third improvement will be to attempt running reaction and absorption simultaneously, in the same container. Since past efforts to do this have worked poorly, we expect this goal will be hard to achieve. Still, when all three improvements are realized, we will be close to a successful process that might be practical to implement in new, small facilities. In the same timeframe, we hope to have the first implementation well on the way in Morris, and this will provide Activity 3 investigators the chance to check and advance their models for future implementations.

Once the lab studies are successful, research efforts at the WCROC Pilot Plan will be extended to operate the system to duplicate the operational parameters of the lab system. Operating conditions to duplicate would include similar gas pressures, temperatures, and molar ratio of gases. This activity will provide a baseline for the conventional technology of the pilot plant, which can then be compared to the performance with new technology used in the lab and which can be implemented in the future with the pilot plant. The control and data acquisition systems will be enhanced in the WCROC pilot plan to achieve the desired comparisons.

Summary Budget Information for Activity 1: **ENRTF Budget: $404,951**
Amount Spent: $ 0
Balance: $404,951

Outcome	Completion Date
1. Scale-up principles to optimize the absorbent-enhanced reactor using ammonia absorption packed columns	January 1, 2016
2. Integration of ammonia absorption packed bed with reactor in the lab, progress in reducing reactor pressure.	July 1, 2016
3. Integration of ammonia absorption and reactor in a single vessel.	July 1, 2017
4. Design principles for future realization of absorbent-enhancement with the pilot plant in Morris MN; seek industrial partners.	July 1, 2017
5. Adaptation of laboratory absorbent-enhanced reactor in a simplified vessel with pressure swing operation, for use in distributed production.	July 1, 2018
6. Establish baseline operating parameters in the pilot plant consistent with optimized absorbent-enhanced reactor operation. Pursue implementation opportunities.	July 1, 2018

Activity Status as of January 1, 2016:

Activity Status as of July 1, 2016:

Activity Status as of January 1, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 1, 2018:

Final Report Summary:

ACTIVITY 2: ***Low pressure ammonia synthesis using non-thermal-plasma***
Description: The second technology developed by our team is Non-Thermal Plasma (NTP) Assisted Catalysis, which is an alternative synthesis method to high temperature and pressure method for ammonia production. A catalytic non-thermal plasma reactor can produce ammonia at much lower temperatures and pressures than the conventional Haber-Bosch ammonia synthesis process.

Non-thermal plasma (NTP) assisted catalysis is highly scalable and portable and can be conducted in temperatures and pressures much lower than those used in traditional catalytic reactions. Therefore the NTP method would enable synthesis of ammonia from renewable hydrogen in scales and conditions achievable on farms and renewable hydrogen production sites. Furthermore, the conversion and energy efficiency of NTP assisted ammonia synthesis can be significantly improved through optimizing synthesis catalysts, ammonia absorbers-catalysts, nitrogen and hydrogen recycling, and temperature control. The techno-economic feasibility and environmental impacts of the technology can be adequately evaluated on a pilot demonstration NTP based ammonia production system. The goal of this activity is to develop, demonstrate, and evaluate a novel NTP based technology for production of ammonia locally and sustainably.

One postdoctoral research fellow (1 FTE) will be employed to conduct the work outlined in this section. Tasks 1 and 3 will leverage the outcome from an MNDrive funded project (2 years). The focus of the present activity is to develop and optimize ammonia absorption process and system, integrate individual processes, and develop a pilot scale facility for testing, evaluation, and demonstration.

Task 1: Selection and testing of catalyst systems for low temperature ammonia synthesis
A project funded by MNDrive will be focused on development of catalyst system for low temperature ammonia synthesis. The outcome will be leveraged by the present LCCMR project. The catalyst systems with acceptable performance in terms of conversion and energy efficiency will be selected for the study and will be tested together with the ammonia absorption process and new NTP reactors under different operational conditions.

Task 2: Development of ammonia absorption systems for use in the NTP system
Improvement of the equilibrium reaction yield of ammonia synthesis at low temperature and low pressure requires separation and removal of ammonia from the reactor during reaction. Several alkaline earth metal halides and zeolites have been found to have ammonia absorption capacity. Use of ammonia absorbents for separation of ammonia during synthesis, especially at low pressure has not been extensively studied. The sorption and desorption behaviors of ammonia absorbents at low temperature and low pressure are not well documented. Furthermore, the possible role of absorbents as synthesis catalysts in NTP assisted catalysis has not been investigated.

Our preliminary study showed that ammonia absorption using $MgCl_2$ and zeolite as absorbents were quite fast and effective. The data suggests that the role of the adsorbent in the new ammonia synthesis system is two-fold: to achieve complete adsorption of the ammonia formed in the catalytic NTP reactor and to facilitate further synthesis of ammonia on the absorbent surface with the remaining active radicals generated in the NTP discharge process. The objective of this experiment is to study the sorption and desorption behaviors and additional synthesis activity of alkaline earth metal halides ($MgCl_2$, $CaCl_2$, $CaBr_2$, $SrCl_2$, and $SrBr_2$) and zeolites in our NTP assisted ammonia synthesis process. The ratio of absorbent to flow rate, absorption temperature and pressure, and placement of absorbents will be studied. Effective desorption methods and efficient desorption scheme will be developed.

Task 3: NTP reactor development and process optimization
This effort will leverage the outcome from the MNDrive funded project. A new NTP reactor will be designed based on the best configuration developed from the MNDrive project. This reactor will be used to further study and optimize the catalyst and absorbent systems. It will serve as the prototype modular unit for the pilot scale facility.

Task 4: Process and system integration and pilot facility development and testing
With the knowledge and understanding generated through Tasks 1-3, we will integrate individual processes into the circulation system. Key components of the facility will include reaction gas feeding, NTP reactor with catalysts, ammonia absorption, ammonia desorption, unreacted gas recycling, flow rate control, temperature control, and product storage. The pilot facility will be built with ability to control and monitor temperature and pressure and provide easy access to sampling.

After the pilot facility is assembled, we will carry out extensive intermittent and continuous operations to test the performance and stability of the facility. Operational conditions including temperature, feeding gas flow rate, and circulation flow rate, will be optimized. Mass and energy balancing will be carried out to determine the conversion and energy efficiency.

Task 5: Technology demonstration
After Task 4 is completed, we will move to demonstrate pilot facility in partnership with LCCMR. At least five demonstrations will be made to stakeholders including state agencies, private investors, academic researchers, and the public. Demonstration events will be broadly publicized through various channels and media. The demonstration events will be one of our major findings dissemination efforts.

Summary Budget Information for Activity 2: **ENRTF Budget: $192,963**
Amount Spent: $ 0

Balance: $192,963

Outcome	Completion Date
1. High performance catalyst systems will be selected from leveraging research activities and tested under NTP conditions.	January 1, 2016
2. Efficient ammonia absorption systems will be developed and evaluated.	January 1, 2016
3. New NTP reactor will be development and used for process optimization	July 1, 2017
4. Processes will be integrated and a pilot scale facility will be designed, fabricated, and tested.	January 1, 2018
5. The entire technology will be demonstrated to stakeholders	July 1, 2018

Activity Status as of January 1, 2016:

Activity Status as of July 1, 2016:

Activity Status as of January 1, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 1, 2018:

Final Report Summary:

ACTIVITY 3: ***Integration, modeling, planning for various economic and policy scenarios***
Description: Research will be pursued at the Morris pilot plant facility analyzing ongoing dynamics and economics of the state-of-the-art existing pilot plant. This will inform modeling and economic research, better enabling judgment of implementation opportunities with the cutting-edge technologies of Activities 1 and 2. The information 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.

Current efforts are focused on the pilot plant being operated as close as possible to “commercial” operation in order to obtain consistent data. The production data from the pilot plant will be inputted into the spreadsheet model to refine the economic evaluation. In the coming year we shall also study opportunities to improve conversion efficiencies at appropriate scale economies capable of utilizing stranded wind power in corn producing areas in smaller scale anhydrous ammonia production facilities. The use of absorbents to enhance the efficiency of catalysts is expected to favor development of smaller scale ammonia production facilities. At this time, there seems to be interest in building smaller scale, and more widely distributed anhydrous ammonia facilities in the U.S., in part encouraged by the lower prices of natural gas.

Activities under this track with the LCCMR project will focus on systems level analysis and evaluation of the different technologies. The goal is to optimize the different designs, explore possible synergies between them, and determine the economic and policy environment that will enable the proposed distribute production paradigm to be successful.

Task 1: Process simulation, design and optimization

We will develop first principles process models for the different production technologies, which will be used to determine optimal operating conditions to minimize the cost of production of ammonia, minimize the amount of byproducts (and hence, the environmental impact), and maximize energy efficiency. For example, for the absorbent-enhanced ammonia synthesis, we will evaluate the range of temperatures and pressures that will allow on one hand sufficiently high conversion, but also low energy requirements. We will also evaluate the performance of alternative absorbent materials. These tasks are too expensive and time consuming to determine experimentally, but can be performed easily through modeling and simulation. Similarly, for the non-thermal plasma-based process, we will examine the interplay between the energy requirements of the plasma reactor and its performance. Close interaction with the experimental effort will allow obtaining the necessary data for model validation in these efforts. Simulation studies will also allow us to address process modifications to overcome performance bottlenecks, as well as scale up issues.

Task 2: Advanced use of pilot plant operation and analysis

The WCROC pilot plant will be operated in a series of test runs to determine optimized operating conditions. The test runs will mimic scenarios developed through the techno-economic modeling studies. Operating pressures, temperatures, molar ratios, and other process variables will be refined to determine the optimal technical and economic parameters. Inputs such as hydrogen, nitrogen, and water will be determined and the resulting anhydrous ammonia output will be measured. To achieve optimum performance, power units within the hydrogen production system will be refurbished and tested prior to the test runs. An enhanced Supervisory Control and Data Acquisition System (SCADA) will replace the current software and hardware to allow safe and efficient test runs. Software will be added to a data historian to store key information during the test runs. Data from the pilot plant and the wind turbine are essential for use in evaluating policy, economic, and business model scenarios.

Task 3: Enterprise-level analysis and evaluation: impact of economic and policy considerations

The proposed research promotes a new paradigm of distributed production of fertilizers with reduced environmental impact. Successful deployment of such facilities will depend both on the technical feasibility of the underlying technologies (addressed in the previous tasks), but also on the broader economic, business and policy environment. Some of the questions that we will address in this task are:

a. What is the optimal scale-down strategy to optimize the overall, industry-level performance at a regional scale? In other words, what is the optimal capacity, location and technology of choice for these distributed facilities that will optimize the overall supply chain?
b. What is the optimal way to integrate these distributed facilities in the current fertilizer production infrastructure? One could envision that even if conventional fertilizer supplies are still used, such facilities can provide important flexibility and resilience in mitigating price increases or demand peaks. What is the business opportunity in this context?
c. How can the tradeoffs between cost and environmental impact be assessed in a broader policy context?

Summary Budget Information for Activity 3:

ENRTF Budget:	**$402,086**
Amount Spent:	**$ 0**
Balance:	**$402,086**

Outcomes	**Completion Date**
1. Conduct techno-economic evaluation, policy analysis, and feasibility assessment of	July 1, 2016

the current Morris pilot plant	
2. Economics-of-scale analysis showing the Morris pilot plant conventional technology at a range of scales, up to county-level	July 1, 2016
3. Preliminary modeling and optimization of absorbent-enhanced ammonia synthesis	January 1, 2017
4. Estimated demand for renewable low-carbon ammonia for organic and advanced biofuel production in Minnesota and the Upper Midwest	January 1, 2017
5. Policy discussion of statewide implementation of revenue-neutral carbon tax applied to fossil-energy-derived ammonia, incentivizing renewable low-carbon ammonia	January 1, 2017
6. Complete first phase of pilot plant test runs	July 1, 2017
7. Techno-economic analysis and feasibility assessment of novel technology - absorbent-enhanced ammonia synthesis	July 1, 2017
8. Techno-economic analysis of distributed ammonia production in Minnesota using multiple technologies	January 1, 2018
9. Revision of capital cost of Morris-technology units (at various scales) using absorbent-enhanced synthesis (reducing capital cost)	January 1, 2018
10. Formulate a development and commercialization strategy: Investigation of interest of venture capitalists and coops in renewable fertilizer in Minnesota; Report opinions of coop bankers for financing multiple distributed ammonia production units; Report opinions of international parties interested in this MN-based technology around the world.	July 1, 2018
11. Economic analysis of distributed ammonia production in Minnesota using alternative hydrogen and power sources (cf. those used in Morris)	July 1, 2018

Activity Status as of January 1, 2016:

Activity Status as of July 1, 2016:

Activity Status as of January 1, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 1, 2018:

Final Report Summary:

ACTIVITY 4: ***Exploring the capture of ammonia with hydrochar for time-release field application***
Description: The third technology will explore a cutting-edge use of hydrochar, a material derived from biomass that acts as a soil amendment, to facilitate time-release field distribution of ammonia. The technology for production of this material has been developed so far by Prof. Ken Valentas in the University of Minnesota Biotechnology Institute, and he will be exploring its use in agriculture with separate support. As we near deployment of new local ammonia production, and as he establishes more knowledge of the behavior of hydrochar, we will partner to explore how much it can further enhance the viability of local ammonia production and distribution and impart time-release capabilities. Hydrochar is a porous carbonaceous material from the hydrothermal carbonization of biomass (which can be food processing waste, fermenter residue, manure, etc.) This material promises to provide superior economics and soil amendment properties. We will be able to help assess the potential for holding ammonia for targeted, low-runoff, time-release delivery to fields. We judge that we can evaluate this alternative using one graduate student for a six-month period after the Valentas team has further developed and characterized the performance of these materials.

Summary Budget Information for Activity 4: **ENRTF Budget: $ 0**
(partnership with Valentas project)

Amount Spent: $ 0
Balance: $ 0

Outcome	Completion Date
1. Ammonia sorption characteristics on hydrochar	July 1, 2017
2. Ammonia release characteristics with hydrochar	July 1, 2018

Activity Status as of January 1, 2016:

Activity Status as of July 1, 2016:

Activity Status as of January 1, 2017:

Activity Status as of July 1, 2017:

Activity Status as of January 1, 2018:

Final Report Summary:

V. DISSEMINATION:
Description: We will arrange regular workshops and conferences with stakeholders; with an enabling project currently supported by the University, we have already begun this series by convening a meeting this month in conjunction with the Minnesota Renewable Energy Roundtable forum. This meeting, facilitated by Steve Kelley, explored the strengths, weaknesses, opportunities, and threats regarding the proposed research and technology development. We had representatives from renewable energy and agricultural businesses, non-profits, Minnesota Department of Agriculture, commodity organizations and government staff. At the end of each grant year, we plan to hold further stakeholder meetings to help assess progress toward achieving research milestones. The names of participants and the meeting minutes will be submitted with our reports.

We will also present the results of our work at regional conferences. We aim to submit invention disclosures with the University and pursue partnerships with companies that can facilitate the deployment of our new technologies, both at Morris and beyond. Finally, we intend to pursue academic publication resulting from this research.

Status as of January 1, 2016:

Status as of July 1, 2016:

Status as of January 1, 2017:

Status as of July 1, 2017:

Status as of January 1, 2018:

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	**$889,893 total personnel**	
Research assistants: *(supervised by Senior personnel, in specific activities, as shown below)*	*$697,992 subtotal for research assistant personnel*	The 5 (FIVE) research assistants will address the workplan goals under the supervision of the senior personnel. Supervision of the research assistants (graduate students, postdoctoral associates, and an assistant scientist) are described below with the supervising senior personnel.
Senior personnel:	*$191,901 subtotal for senior personnel**	The role of the 8 Senior Personnel includes: • Provide intellectual conception, leadership, perspective and drive; set tone and direction of project; • Advise, direct, supervise, and review performance of research assistants; • Coordinate with other senior personnel and project partners to review project progress and goals; • Arrange, conduct, and review efforts at stakeholder engagement, dissemination, publication, and outreach; • Conduct research reviews both internally and with stakeholders
McCormick, project manager, and also senior personnel responsibilities as described below -	**30,025 McCormick total, 0.04 FTE for 3 years*	
Cussler, *with Dauenhauer and McCormick* *(and with Project Partner Schmidt)* *supervising one postdoctoral associate in Activity 1*	**$16,243 Cussler total, 0.02 FTE for 3 years* **$12,171 Dauenhauer total, 0.02 FTE for 3 years*	
Reese supervising one assistant scientist at the Morris pilot plant, supporting Activities 1 and 3	**Reese effort cost-shared (see other funding)*	
Ruan supervising one postdoctoral associate in Activity 2	**$13,252 Ruan total, 0.02 FTE for 3 years*	
Daoutidis supervising one graduate student in Activity 3 *Daoutidis and McCormick supervising partial effort of one additional graduate student bridging Activities 1 and 3*	**$18,135 Daoutidis total, 0.02 FTE for 3 years*	
Tiffany supervising one graduate student in Activity 3	**$79,413 Tiffany total, 0.25 FTE for 3 years*	
Kelley supporting Activity 3 and also conducting outreach, policy, and stakeholder communications for all Activities	**$22,662 Kelley total, 0.04 FTE for 3 years*	
Professional/Technical/Service Contracts:	$29,200	The maintenance and servicing of the pilot plant equipment and software is fundamental to the progress of this project.

Equipment/Tools/Supplies:	$73,907	The technical work at the pilot plant and the research activities in the laboratories require supplies to be safe and effective. The funding requested may only partially meet the need.
Capital Expenditures over $5,000:	$0	
Fee Title Acquisition:	$0	
Easement Acquisition:	$0	
Professional Services for Acquisition:	$0	
Printing:	$3000	This includes partial support for the costs of reporting, outreach, conference preparation, and publication efforts. The funding requested may only partially meet the need.
Travel Expenses in MN:	$4000	Travel for collaboration and outreach in Morris, the Twin Cities, and further throughout the state. The funding requested may only partially meet the need.
Other:	$0	
TOTAL ENRTF BUDGET:	**$1,000,000**	

Explanation of Use of Classified Staff: NA

Explanation of Capital Expenditures Greater Than $5,000:

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: *ABOUT 4.27 FTE TOTAL*
Five research assistants over three years, leveraged with other funding.

a. 2 postdoctoral associates (each averaging 87.5% FTE appointment over the grant period)
b. 1 graduate student (averaging 83.3% of graduate research assistant effort over the grant period; note that graduate student research assistants can be appointed only at 50% FTE, so this averages 41.7% FTE over the grant period.)
c. 1 additional shared graduate student at average 55% graduate research assistant effort over the grant period - so averaging 27.5% FTE over the grant period.
d. 1 assistant scientist (pilot plant engineer) at 100 % FTE over the grant period.

In addition, 6 senior personnel are appointed for 1-2 weeks for salary each year - *totaling* 0.16 FTE over the grant period. Finally, one senior personnel is appointed 0.25 FTE over the grant period.

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 0.06 FTE

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
University of Minnesota MNDRIVE program	$250,000	$	Concurrent with year 1 of the proposed LCCMR project, leveraging and advancing the workplan objectives
0.04 FTE cost share for Senior Personnel Mike Reese over 3 years	> ca. $11,000		

State			
	$	$	
TOTAL OTHER FUNDS:	**ca. $261,000**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners:

Professor Lanny Schmidt
Professor Ken Valentas (also conducting a related LCCMR project on hydrochar)
Participants in our stakeholder meetings (see dissemination and outreach plans)

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. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
Concurrent with LCCMR Year 1: UMN MNDrive project, year 2	July 2015-June 2016	$250,000
UMN MNDrive project, year 1	July 2014-June 2015	$250,000
UMN Initiative for Renewable Energy and the Environment (IREE) Competitive Large Grant Program, plus matches to two MDRPC grants (see below)	March 2011 - Nov 2014	$513,000
Two grants for Economic Evaluation of Local Ammonia Production from the Minnesota Corn Research and Promotion Council	March 2008 - Nov 2014	$141,600
MN State Bond to plan and construct Renewable Hydrogen and Ammonia Plant	July 2007 - Oct 2013	$2,500,000
UMN College of Food Agriculture and Natural Resource Sciences Match to MN State Bond	July 2007 - Oct 2013	$430,000
ENRTF Wind to Hydrogen Demonstration (final report 2010)	July 2005 - June 2010	$800,000

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:
NOT APPLICABLE

IX. VISUAL COMPONENT or MAP(S):

See accompanying file: "LCCMR Graphic - Renewable and Sustainable Fertilizers FINAL 10-7-14.pdf"

X. RESEARCH ADDENDUM:

See accompanying file

XI. REPORTING REQUIREMENTS:

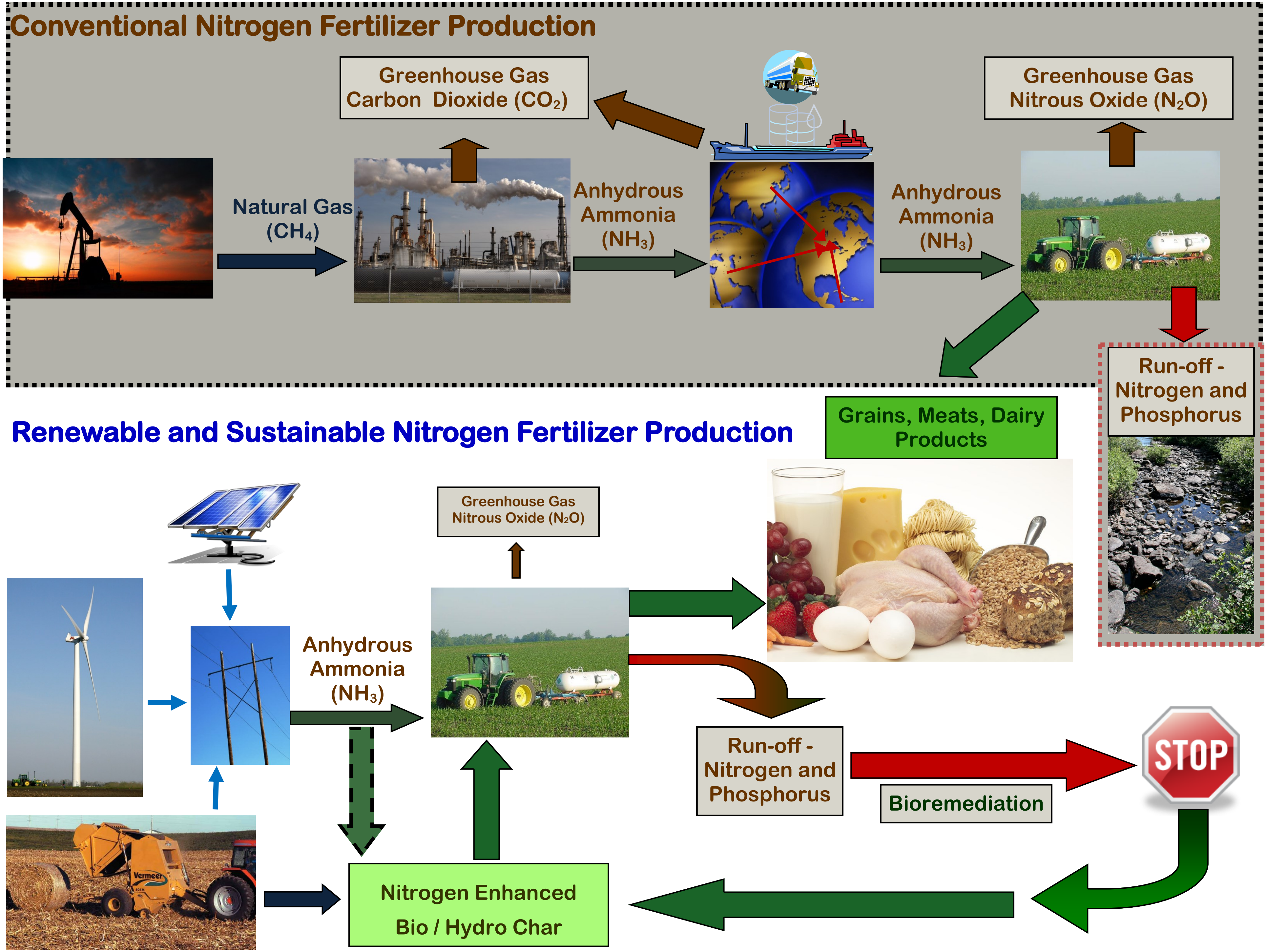
Periodic work plan status update reports will be submitted no later than January 1, 2016; July 1, 2016; January 1, 2017; July 1, 2017; and January 1, 2018. A final report and associated products will be submitted between June 30 and August 15, 2018.

Environment and Natural Resources Trust Fund
M.L. 2015 Project Budget

Project Title: Renewable and Sustainable Fertilizers Produced Locally
Legal Citation:
Project Manager: Alon McCormick
Organization: University of Minnesota
M.L. 2015 ENRTF Appropriation: $1,000,000
Project Length and Completion Date: 3 Years, June 30, 2018
Date of Report: 5/20/2015

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Improve efficiency for absorbent-enhanced ammonia synthesis (Cussler, McCormick, Schmidt, Dauenhauer, Reese)***			***Low pressure ammonia synthesis using non-thermal-plasma (Ruan)***			***Integration, modeling, planning for various economic and policy scenarios (Daoutidis, Tiffany, Kelley, Reese)***				
Personnel (Wages and Benefits)	$378,072	$0	$378,072	$176,211	$0	$176,211	$335,610	$0	$335,610	$889,893	$889,893
PI McCormick $30,025 (74.8% salary, 25.2% benefits) at .04 FTE for 3 years - PI and project manager											
PI Cussler $16,243 (74.8% salary, 25.2% benefits) at .02 FTE for 3 years											
PI Daoutidis $18,135 (74.8% salary, 25.2% benefits) at .02 FTE for 3 years											
PI Dauenhauer $12,171 (74.8% salary, 25.2% benefits) at .02 FTE for 3 years											
PI Kelley $22,662 (74.8% salary, 25.2% benefits) at .04 FTE for 3 years- outreach/discussions with stakeholders and policymakers											
PI Reese $0 (no cost to LCCMR grant, 4% cost share effort) - ROC research and outreach											
PI Ruan $13,252 (74.8% salary, 25.2% benefits) at .02 FTE for 3 years											
PI Tiffany $79,413 (74.8% salary, 25.2% benefits) at .25 FTE for 3 years											
2 Postdoctoral Associates $311,577 (81.7% salary, 18.3% benefits) Position 1 (Cussler lead advisor) at 50% FTE in year 1, then 100% FTE in years 2 and 3 (Activity 1). Position 2 (Ruan lead advisor) at 75% FTE in year 1, then 100% FTE in years 2 and 3 (Activity 2).											
2 Graduate Student Research Assistants $215,998 (61.5% salary, 38.5% benefits (including tuition)) Note maximum FTE appointment for an individual graduate student is 50%. Position 1 (Daoutidis lead advisor): 25% FTE (50% graduate student effort) in year 1, and 50% FTE (100% graduate student effort) in years 2 and 3. Activity 3. Position 2 (Daoutidis/McCormick advisors, shared student, partial appointment): 16.5% FTE (33% graduate student effort) in year 1, 33% FTE (66% graduate student effort) in years 2 and 3. Effort split between Activities 1 and 3 (funds allocated to Activity 1).											
Assistant scientist $170,417 (78.5% salary, 21.5% benefits) (Reese primary supervisor) 100% FTE each year for 3 years. Effort and funds split between Activities 1 and 3.											
Professional/Technical/Service Contracts											
Matrix Tech for programming offsite and onsite, including travel lodging and meals							$14,600	$0	$14,600	$14,600	$14,600
Refurbish and testing of power units - 4 @ $3600 each							$14,600	$0	$14,600	$14,600	$14,600
Equipment/Tools/Supplies											
Pilot plant Supplies - Matrix Software Update for SCADA System (control system for the pilot plant)							$10,888	$0	$10,888	$10,888	$10,888
Pilot plant Supplies - Matrix Software Update for Data Historian (data acquisition system for the pilot plant)							$6,456	$0	$6,456	$6,456	$6,456
Hardware upgrade for SCADA System and Data Historian (essential for operation and analysis of the pilot plant performance)							$3,400	$0	$3,400	$3,400	$3,400
General pilot plant supplies - including safety goggles, gas masks, chemical gloves, chemical suits, chemical boots, gas mask cartridges, water prefilters and filters for the deionized water system, chiller system coolant, calibration gases for safety sensors, and leak detection spray bottles							$9,500	$0	$9,500	$9,500	$9,500

Experimental supplies for laboratory research assistants (apportioned by number of lab-intensive research assistants) : Chemicals, lab analysis, safety and laboratory needs for the chemical-intensive research assistants. Includes: cylinders of nitrogen, hydrogen, and ammonia; magnesium chloride; stainless steel tubing, Swagelok fittings, high pressure/temperature ceramic fittings, thermocouples, gas syringes for chromatograph, chromatograph replacement parts, leak detection fluid and supplies, gloves, emergency gas mask; catalysts, supports, and promoters; zeolite adsorbents; reagents such as ethanol, methyl red, and sulfuric acid; porous ceramic and quartz tubes for NTP reactor; electrodes, minor power supplies; temperature guages, pressure guages, flowmeters, and monitoring equipment; carrier gases (argon, helium) and liquid nitrogen for chromatography; sieves for particle sizing; sample containers	$23,816	$0	$23,816	$15,877	$0	$15,877	$3,969	$0	$3,969	$43,663	$43,663
Printing											
Reporting, grant administration, conference organization, outreach, and publication (partial funding - apportioned by number of senior personnel)	$1,313	$0	$1,313	$375	$0	$375	$1,313	$0	$1,313	$3,000	$3,000
Travel expenses in Minnesota											
In-state travel between Morris and Twin Cities for full-day research collaboration and outreach elsewhere in the state (partial funding, apportioned by number of senior personnel) Roughly monthly visits, ca. $300 for 2 person overnight Morris to TC, ca. $100/person for TC to Morris.	$1,750	$0	$1,750	$500	$0	$500	$1,750	$0	$1,750	$4,000	$4,000
COLUMN TOTAL	**$404,951**	**$0**	**$404,951**	**$192,963**	**$0**	**$192,963**	**$402,086**	**$0**	**$402,086**	**$1,000,000**	**$1,000,000**


Conventional Nitrogen Fertilizer Production
Greenhouse Gas Carbon Dioxide (CO_2)
Greenhouse Gas Nitrous Oxide (N_2O)
Natural Gas (CH_4)
Anhydrous Ammonia (NH_3)
Anhydrous Ammonia (NH_3)
Run-off - Nitrogen and Phosphorus
Grains, Meats, Dairy Products
Renewable and Sustainable Nitrogen Fertilizer Production
Greenhouse Gas Nitrous Oxide (N_2O)
Anhydrous Ammonia (NH_3)
Run-off - Nitrogen and Phosphorus
Bioremediation
STOP
Nitrogen Enhanced Bio / Hydro Char