Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan

Date of Report: January 15, 2014

Date of Next Status Update Report: November 2014

Date of Work Plan Approval:

Project Completion Date: June 30, 2017

Does this submission include an amendment request? NO

PROJECT TITLE: Life Cycle Energy of Renewably Produced Nitrogen Fertilizers

Project Manager: Joel Tallaksen

Organization: Univ. of Minn- West Centeral Research and Outreach Center in Morris

Mailing Address: 46352 State highway 329

City/State/Zip Code: Morris, MN, 56267

Telephone Number: (320) 589-1711

Email Address: tall0007@umn.edu

Web Address: http://wcroc.cfans.umn.edu/RenewableEnergy/index.htm
http://renewables. morris.umn.edu/GreenAg (will be established when project is started)

Location: Statewide

Total ENRTF Project Budget: $250,000	
ENRTF Appropriation:	**$250,000**
Amount Spent:	**$0**
Balance:	**$250,000**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 08e

Appropriation Language:
$250,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the West Central Research and Outreach Center in Morris to calculate fossil fuel energy savings and greenhouse gas reductions resulting from the use of local renewable energy technologies, including biomass gasification, anaerobic digestion, and hydroelectricity to produce fertilizer. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Life Cycle Energy of Renewable Produced Nitrogen Fertilizers

II. PROJECT STATEMENT:

The Minnesota landscape supports over 14 million acres of cropland in grain production. Almost 600,000 tons of nitrogen fertilizers are needed annually to maintain productivity on this land. In energy terms, production of Minnesota's nitrogen fertilizer requires the equivalent of 3,000,000 barrels of oil annually and costs farmers over $400 million. This is a significant use of fossil fuels in the state and results in a considerable amount of greenhouse gas (GHG) emissions. In addition, the absence of fossil energy resources in the State means that these synthetic nitrogen fertilizers must be imported into Minnesota from the other states and overseas.

As an initial step towards developing a renewable nitrogen fertilizer for the State, a pilot plant at the University of Minnesota, West Central Research and Outreach Center (WCROC) uses wind turbine electricity to produce ammonia, the most commonly used nitrogen fertilizer in Minnesota. Initial life cycle assessment (LCA) has shown that the wind to ammonia system is capable of producing ammonia fertilizer with very low fossil energy inputs and fewer GHG emissions; however, intermittent production of wind power would limit ammonia production during calm periods. Minnesota has a broad portfolio of other base-load renewable energy sources renewable technologies capable of more constant generation of the hydrogen rich precursors needed for ammonia production; among these are biomass gasification, anaerobic digestion, and hydropower (using electrolysis). We have designed this project to examine the viability of these base-load renewable energy sources for ammonia production. The work brings together chemical engineering researchers, industry professionals and life cycle assessment specialists to examine the feasibility of producing nitrogen fertilizers using renewable energy sources other than wind.

To analyze these systems, researchers will examine Minnesota gasification, anaerobic digestion and hydroelectric systems to collect data for building computer models of the systems. One type of model will be a life-cycle model that will assess all inputs and outputs to calculate total greenhouse gas emissions and fossil energy input. The other will be a chemical process model that will examine the amount of raw materials and energy needed to make ammonia and the relative efficiency and cost of the process. For each of these models, the work is done in two phases; building the model from energy production data and ammonia production equipment specifications, and then working with the model to accurately predict the operations of the technology. A final piece of this project is working to disseminate project information via our website, print media, and stakeholder meetings.

A key objective in developing this information is to *identify the viability of producing nitrogen fertilizers using different renewable energy technologies,* which could significantly reduce fossil energy consumption and GHG emissions from the large agricultural sector in the State. Another important objective is to *provide options for expanding local renewable energy use in Minnesota's industrial base*. This would help *promote economic development and spur job creation in rural areas* and thus, extend the economic benefits beyond agriculture. The project also examines a potential strategy of improving the overall sustainability of agriculture as desired by the market place. A final objective is to *further develop the knowledge base of Minnesota researchers to conduct LCAs and techno-economic feasibility analyses of renewable energy and nitrogen fertilizer production systems.* We feel that these project objectives fit very well with WCROC's overall goal of *reducing fossil energy use in agriculture and enhancing rural communities.*

III. PROJECT STATUS UPDATES:

Project Status as of *(November 30, 2014)*:

Project Status as of *(June 30, 2015)***:**

Project Status as of *(November 30, 2015)***:**

Project Status as of *(June 30, 2016)***:**

Project Status as of *(November 30 , 2016)***:**

Overall Project Outcomes and Results (June 30, 2017)**:**

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: *Life Cycle Assessment Modeling of Renewable Nitrogen Production*
Description:
LCA modeling for renewable energy systems will use data from facilities such as the biomass gasification system located at Chippewa Valley Ethanol Cooperative, in Benson, MN, a local anaerobic digestion system, and a representative Minnesota hydroelectric production system. The research will be based on standard ISO14040 life cycle assessment methodology and examining energy (both renewable and fossil) and GHG emissions. The first major tasks to complete this activity is working to collect data at the renewable energy facilities and documenting all inputs and outputs needed in the energy production process. This includes understanding the operation of the renewable energy technology, assessing the amount of infrastructure needed, and fully examining potential impacts of each input and output. Once this information is documented, then the next task is to create a model that allows all the data to be used in an integrated manner to calculate the overall energy use and GHG emissions. The primary focus of these efforts will be on the biomass gasification and anaerobic digestion modeling as these are most common in the agricultural regions of the state and have more potential for future installations in Minnesota. Hydro-electric based fertilizer production modeling will be somewhat less detailed and rely more on database data as an overview of the technology for determining life-cycle impacts.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 98,879
Amount Spent: $ 0
Balance: $98,879

Activity Completion Date: 11/2016

Outcome	Completion Date	Budget
1. Life Cycle Assessment of Ammonia Production Via Biomass Gasification	9/2015	$32,959
2. Life Cycle Assessment of Ammonia Production Via Anaerobic Digestion	4/2016	$32,959
3. Life Cycle Assessment of Ammonia Production Via Hydro-electric Power	11/2016	$32,959

Activity Status as of *(November 30, 2014)*:

Activity Status as of *(June 30, 2015)***:**

Activity Status as of *(November 30, 2015)***:**

Activity Status as of *(June 30, 2016)***:**

Activity Status as of *(November 30, 2016)***:**

Final Report Summary:

ACTIVITY 2: *Technological and Economic Feasibility of Renewable Nitrogen Fertilizer Production*
Description: The technological and financial feasibility of adding ammonia production capabilities onto existing Minnesota commercial scale renewable energy facilities will be studied. As with LCA analysis in Activity 1, the first step is to collect data on the renewable energy technology and its inputs into ammonia production. However,

the data collection will review aspects related to the chemistry, electronics, and types of equipment used in the processes. Process modeling will then use the Aspen+ modeling tool to examine simulations of production process chemistry, equipment needs, and facility costs. Logistical considerations such as biomass and manure processing and transport will be added to the models to make them more applicable to real-world situations. The output from these analyses will be used to estimate capital costs and economic viability of the production technologies. The primary focus of these efforts will be on the biomass gasification and anaerobic digestion modeling as these are most common in the agricultural regions of the state and have more potential for future installations in Minnesota. Hydro-electric based fertilizer production modeling will be somewhat less detailed and rely more on database data as an overview of the technology for determining life-cycle impacts.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 127,129
Amount Spent: $ 0
Balance: $ 127,129

Activity Completion Date: 11/2016

Outcome	Completion Date	Budget
1. Techno-Economic Model of Ammonia Production Via Biomass Gasification	9/2015	$ 42,376
2. Techno-Economic Model of Ammonia Production Via Anaerobic Digestion	4/2016	$ 42,376
3. Techno-Economic Model of Ammonia Production Via Hydro-electric Power	11/2016	$ 42,376

Activity Status as of *(November 30, 2014)*:

Activity Status as of *(June 30, 2015)***:**

Activity Status as of *(November 30, 2015)***:**

Activity Status as of *(June 30, 2016)***:**

Activity Status as of *(November 30, 2016)***:**

Final Report Summary:

ACTIVITY 3: *Analysis of Impacts on Agriculture and Information Dissemination*

Description: The results from activities 1 and 2 will be used to generate Minnesota specific energy and greenhouse gas statewide impact estimates of using renewable energy sources to produce ammonia fertilizers. The data will also be used to estimate impacts on the lifecycle energy and emissions of Minnesota agriculture and agricultural products. Results will be disseminated to stakeholders via stakeholder meetings, web publication of study findings, hard copy distribution of information, and publication of scientific papers.

Summary Budget Information for Activity 3:

ENRTF Budget: $ 23,992
Amount Spent: $ 0
Balance: $ 23,992

Activity Completion Date: 6/2017

Outcome	Completion Date	Budget
1. Assessment of Fossil Energy Impacts on Agriculture	5/2017	$ 15,000
2. Industry Report on Feasibility of Different Renewable Production Systems	5/2017	$ 5,000
3. Information Dissemination Via Meetings and Print and Web Publications	6/2017	$ 3,992

Activity Status as of *(November 30, 2014)*:

Activity Status as of *(June 30, 2015)***:**

Activity Status as of *(November 30, 2015)***:**

Activity Status as of *(June 30, 2016)***:**

Activity Status as of *(November 30, 2016)***:**

Final Report Summary:

V. DISSEMINATION:

Description:
There are several audience for the information from this project, including farmers, businesses, investors, scientists, and community development organizations. Connecting with these audiences will involve several strategies. Project staff will conduct stakeholder meetings and speak at regional/national talks and conferences about the project goals and findings. The project will be documented in a final comprehensive white-paper report geared toward industry and investor audiences. A web page will be set up on WCROC's existing renewable energy websites (renewables.morris.umn.edu & wcroc.cfans.umn.edu) to provide project information, updates, and the final report. The findings will also be available for use in peer-reviewed scientific journal articles prepared by the study's technical staff. WCROC staff will also maintain a collection of printed and digital outreach material for distribution to interested parties.

Status as of *(November 30, 2014)*:

Status as of *(June 30, 2015)***:**

Status as of *(November 30, 2015)***:**

Status as of *(June 30, 2016)***:**

Status as of *(November 30, 2016)***:**

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$ 97,205	Personnel: Project manager/Lead researcher (.5 FTE total over 3 years), Junior scientist (1 FTE total over 1 year), student intern (.25 FTE total)
Professional/Technical/Service Contracts:	$ 145,000	Contracts: Chemical engineering Researcher Team, Lund University Sweden. ($80,000) Responsible for analyzing the feedstocks, chemistry, and equipment, at the renewable energy sites in Minnesota. (Estimated 1 FTE). Lifecycle assessment research team, Swedish agricultural University. ($50,000) Will assist University of Minnesota researchers with fertilizer specific pathways for analyzing lifecycle assessment (Estimate 1 FTE). Funds for Chippewa Valley ethanol Cooperative ($3,750) to compensate for staff time allocated for this project. Similar funds for entity operating and anaerobic digestion system ($3,750), Entity would work with University of Minnesota research staff to identify inputs, outputs, and equipment needed for converting biogas into ammonia fertilizer.
Equipment/Tools/Supplies:	$ 4,295	Equipment/Tools/Supplies: General supplies for production of outreach materials, collection of data, and general project operations. Software updates to LCA software ($1800).
Printing:	$ 1,500	Costs of printing outreach material for use at meetings and for distribution to stakeholders.
Travel Expenses in MN:	$ 2,000	Travel: In-State travel to research facilities being examined over the three-year period of the study. This will include vehicle mileage at standard government rate.
TOTAL ENRTF BUDGET:	**$ 250,000**	

Explanation of Use of Classified Staff: n/a

Explanation of Capital Expenditures Greater Than $5,000: n/a

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.75 FTE

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: 2.0 FTE

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
	$	$	
State			
Univ. of Minn.	$130,000	$ 0	The University of Minnesota is forgoing the typical 52% federally negotiated indirect cost recovery normally associated with research grants. This funding covers facilities, support staff, and other University activities that are not directly part of the research, but must be present to support research activities.
TOTAL OTHER FUNDS:	**$130,000**	**$ 0**	

VII. PROJECT STRATEGY:

A. Project Partners:

This project will bring together a variety of specialists to complete the different technical, economic, energy and agricultural aspects of this project. The University of Minnesota, WCROC will coordinate the research efforts and provide overall project management. WCROC's experience in combining renewable energy systems with ammonia production, along with our interactions with local industry and other stakeholders allows WCROC a unique opportunity to evaluate renewable nitrogen fertilizer production systems. Chippewa Valley Ethanol Cooperative ($3,750) will be assisting with modeling the biomass energy to ammonia production in a gasification system. They have a gasification platform capable of using local biomass to produce hydrogen rich gas needed for ammonia production. We also intend to partner with a regional anaerobic digestion system operator. The team researching technology in these facilities includes Dr. Christian Hulteberg and his research group ($80,000)from Lund University, Sweden. His specialty is chemical engineering and, specifically, methods of production of hydrogen-based chemicals, such as ammonia. His group also examines the economics of production systems. Dr. Serina Ahlgren and her group from the Swedish Agricultural University ($50,000) are experts in life cycle analysis of nitrogen fertilizer production systems. Working with these partners will also allow WCROC to further expand its life-cycle assessment capabilities, and thus grow Minnesota's expertise in what has become an important tool for evaluating industrial systems.

B. Project Impact and Long-term Strategy:

The WCROC Renewable Energy Research Group's overall goal is to assist farmers and rural committees by examining energy technologies to help reduce agricultural energy related production costs, promote rural based renewable energy, and expand opportunities for rural economic development. The long-term strategy is to conduct hands-on research and demonstration on renewable energy or energy conservation technologies that are close to being ready to deploy in rural applications. By examining commercial scale technology in applied situations, we can generate the data that shows our stakeholders the benefits and challenges of the technologies and methods being used to reduce their communities' dependence on imported energy. They can then decide whether these technologies would be of benefit to their farm, business, or local community.

This project is designed to examine the feasibility of using local renewable energy generation to make a value added fertilizer product that is needed for Minnesota Agriculture. The data from the project would be provided to both the private sector and other renewable energy researchers to allow them to consider further work with the technology for making nitrogen fertilizer from renewable energy sources common in Minnesota. Already, the existing project examining wind to nitrogen fertilizer project has garnered a great amount of commercial interest due to the value of fertilizers and the potential for renewable wind energy in Minnesota. We think that other renewable energy technologies could have a place in helping to generate renewable fertilizers needed in the state. This project will provide stakeholders with information about the economics of this process as well as the potential environmental impacts from using renewably produced fertilizers.

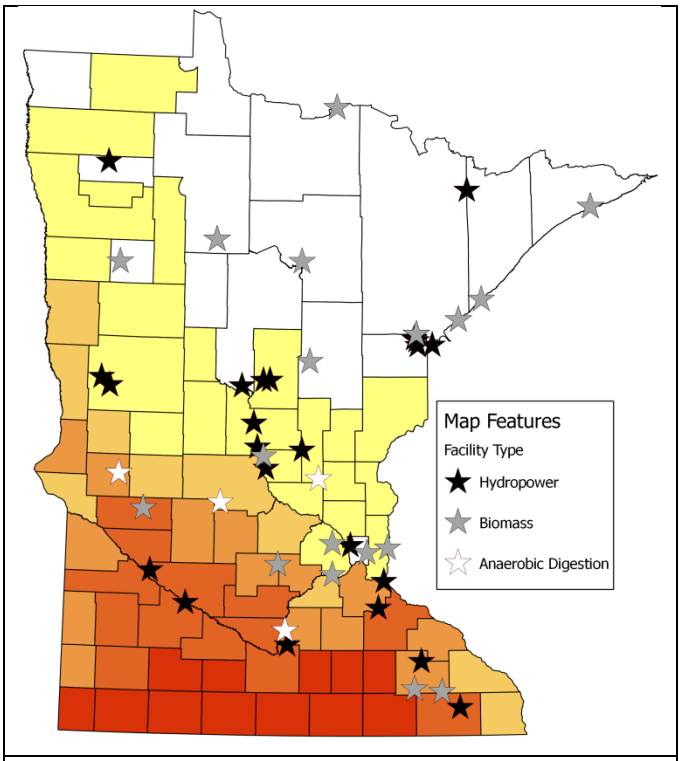
C. Spending History:

Funding Source	**M.L. 2008 or FY09**	**M.L. 2009 or FY10**	**M.L. 2010 or FY11**	**M.L. 2011 or FY12-13**	**M.L. 2013 or FY14**
2005 State of MN Bonding $2.5 M					
LCCMR ($800,000) (M.L. 2005)					
Univ. of Minn. ($430,000- 2005)					
Private Funding			$100,000		
IREE (Univ. of Minn)		$77,606			
Swedish Energy Agency				$120,000	
Note: These funds are for work on the wind energy to ammonia project, which was the first part of the effort to examine renewably produced fertilizer and is the groundwork and comparison used in the efforts for this project. Much of this funding was pledged for planning and construction (well prior to 2009). Operation of the ammonia facility began in 2012).					

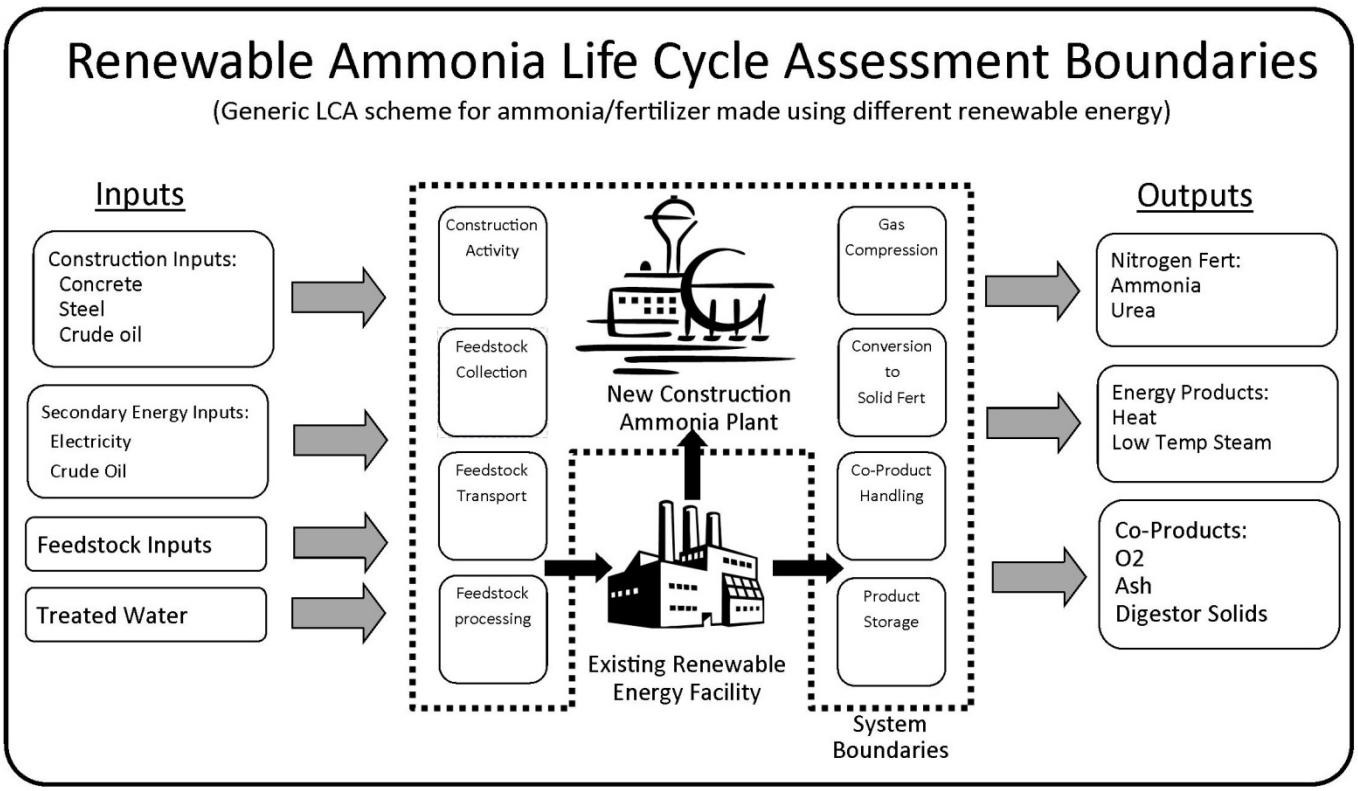
VIII. ACQUISITION/RESTORATION LIST: n/a

IX. VISUAL ELEMENT or MAP(S):

The **map (right)** illustrates the diversity of renewable energy facilities in Minnesota. It shows a selection of Minnesota based renewable energy facilities using biomass, hydropower, and anaerobic digestion to produce electricity, heat, and biomass, plus other co-products. This is overlaid against the areas of the state where there is a significant demand for nitrogen fertilizers. The **figure (below)** shows the major factors considered in a lifecycle assessment of renewably produced ammonia. The inputs included in the assessment would be items needed to build the ammonia production component of the system, secondary fossil energy inputs such as fuel, electricity, plus any treated water needed. The outputs would include the nitrogen fertilizer, any energy such as heat or steam, and co-products such as digester solids, ash, or purified oxygen. The type of renewable system would change some inputs and outputs, with biomass and anaerobic digestion facilities needing significantly more inputs, while hydro power would need less. These same inputs and outputs would be important for the economic assessment of the system, which would also include other logistical considerations depending on the renewable energy source.



Selected Renewable Energy Facilities in Minnesota and Corn Production Regions. Facilities indicated are a representative sampling of gasification, anaerobic digestion and hydropower systems. Darker areas indicated higher corn production, which typically requires more nitrogen.



X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: n/a

XI. RESEARCH ADDENDUM: n/a

XII. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than November 2014, June 2015, November 2015, June 2016, and November 2016. A final report and associated products will be submitted between June 30 and August 15, 2017.

Environment and Natural Resources Trust Fund

M.L. 2014 Project Budget

Project Title: Life Cycle Energy of Renewably Produced Nitrogen Fertilizers

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 08e

Project Manager: *Joel Tallaksen*

Organization: *University of Minnesota, West Central Research and Outreach Center in Morris*

M.L. 2014 ENRTF Appropriation: $ *250,000*

Project Length and Completion Date: 3 Year, June 30, 2017

Date of Report: August *2017*

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	LCA of Renewable Nitrogen Production			Techno-economics of Renewable N Production			Impacts on Agriculture and Info. Dissemination				
Personnel (Wages and Benefits)	$38,481	$0	$38,481	$38,481	$0	$38,481	$20,243	$0	$20,243	$97,205	$97,205
Scientist (0.5 FTE total over 3 years, $ 42,138, 63 % salary & 37% fringe)											
Jr. Scientist (1 FTE total over 1 year, $49,049, 63 % salary & 37 %fringe)											
Student Intern (.25 FTE-14 Weeks, $6,016, 93 % salary and 7 %fringe)											
Professional/Technical/Service Contracts											
Lifecycle assessment research team, Swedish agricultural University. ($50,000) Will assist University of Minnesota researchers with fertilizer specific pathways for analyzing lifecycle assessment (Estimate 1 FTE).	$50,000	$0	$50,000	$0	$0	$0	$0	$0	$0	$50,000	$50,000
Chemical engineering Researcher Team, Lund University Sweden. ($80,000) Responsible for analyzing the feedstocks, chemistry, and equipment, at the renewable energy sites in Minnesota. (Estimated 1 FTE).	$0	$0	$0	$80,000	$0	$80,000	$0	$0	$0	$80,000	$80,000
Funds for Chippewa Valley ethanol Cooperative ($3,750) to compensate for staff time allocated for this project. CVEC would work with University of Minnesota research staff to identify inputs, outputs, and equipment needed for converting producer gas into ammonia fertilizer.	$3,750	$0	$3,750	$3,750	$0	$3,750	$0	$0	$0	$7,500	$7,500
Funds for entity operating and anaerobic digestion system ($3,750), whose staff time would be used to work with University of Minnesota research staff to identify inputs, outputs, and equipment needed for converting biogas into ammonia fertilizer.	$3,750	$0	$3,750	$3,750	$0	$3,750	$0	$0	$0	$7,500	$7,500
Equipment/Tools/Supplies											
General Research supplies - sampling equipment feedstocks/products , tools for measuring, saftey equipment, lab research notebooks	$300	$0	$300	$300	$0	$300	$300	$0	$300	$900	$900
Life cycle assessment software update	$1,750	$0	$1,750	$0	$0	$0	$0	$0	$0	$1,750	$1,750
Outreach supplies- binders, cd, labels, nametags, and other supplies for outreach meetings as allowed by the Univesity/State	$348	$0	$348	$348	$0	$348	$949	$0	$949	$1,645	$1,645
Printing	$0	$0	$0	$0	$0	$0	$1,500	$0	$1,500	$1,500	$1,500
Travel expenses in Minnesota											
Mileage to research and dissemination sites	$450	$0	$450	$450	$0	$450	$950	$0	$950	$1,850	$1,850
Meals as allowed by University during travel	$50	$0	$50	$50	$0	$50	$50	$0	$50	$150	$150
Other											
COLUMN TOTAL	$60,398	$0	$60,398	$88,648	$0	$88,648	$3,749	$0	$3,749	**$152,795**	**$250,000**