Environment and Natural Resources Trust Fund
2018 Request for Proposals (RFP)

Project Title: **ENRTF ID: 188-F**

Converting Agricultural Wastes into Energy, Polymers, and Fertilizers

Category: F. Methods to Protect or Restore Land, Water, and Habitat

Total Project Budget: $ 949,000

Proposed Project Time Period for the Funding Requested: 4 years, July 2018 to June 2022

Summary:

Swine manure, sugar processing waste, and ethanol fermentation waste contain significant amounts of unused energy and nutrients. This project will revolutionize waste management by converting these waste into primary resources.

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Sponsoring Organization: U of MN

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The visual map shows manure and sugar beet and ethanol waste being cicled back into energy, fertilizer, polymers, feed, and recycled water.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

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

_____ Capacity Readiness _____ Leverage _______ TOTAL ______%

PROJECT TITLE: Converting Agricultural Wastes into Energy, Polymers, and Fertilizers

I. PROJECT STATEMENT

Swine manure, sugar beet waste, ethanol DDGs, and by-products from ethanol cellulosic fermentation waste carry with them a significant amount of energy and nutrients that can now, due to the advances in technology, be recycled back into the system as primary resources. This project is the advancement of the currently funded LCCMR project “Clean water/renewable energy from beet waster/ manure (Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 08f)” that is showing great potential, at the benchtop scale, to revolutionize agricultural waste management. We will build a scale up (250-gallon capacity) system which will use swine manure in combination with beet sugar, or ethanol DDGs, or ethanol cellulosic fermentation wastes to produce biogas, fertilizer (struvite and a designer fertilizer), biodegradable polymers, and potentially feed for livestock. The system is comprised of two 250-gallon digesters to produce hydrogen and methane gases (will use these to produce ammonia); along with a struvite (ammonium phosphate mineral) recovery system to create a designer fertilizer with predictable release rates; followed by a 250-gallon capacity fermenter to produce additional hydrogen gas, biodegradable polymers and protein for animal feed using non-sulfur purple bacteria. With this approach, we expect that a near-closed system can be developed where most of the energy and fuels used for the production of corn and sugar beet can be regenerated.

Minnesota is ranked #2 in hog production, generating about 11 million tons of swine manure; #1 in sugar beet production generating over 1 million tons of waste; and #5 in corn ethanol production generating 3 million tons of dried distiller’s grain (DDG) annually. Land application of over 1 million tons of sugar and ethanol processing wastewater and application of over 11 million tons of swine manure threatens water resource and increases surface and groundwater pollution. Well over $10 million can be saved for sugar beet ethanol processers annually for wastewater treatment; bio-electricity of at least 143 million kWh ($9.72 million) can be produced yearly from waste materials (at a ratio of 5 (pig manure) to 1 (sugarbeet wastewater)); 15,560 tons of ammonia/phosphate fertilizer (struvite) can be produced annually ($5 mil value) with even more value added when the designer fertilizer is considered. These facts show that this project can result in a win-win situation.

The goals of this research are:

- Determine how much methane and hydrogen gas can be recovered at the large scale from swine manure, DDGs, cellulosic fermentation waste, and sugar beet waste
- Produce a designer fertilizer with predictable nutrient release rates that best fits the environmental conditions of different regions of the state
- Produce biodegradable polymers and protein for animal feed from non-sulfur purple bacteria
- Revolutionize agricultural waste management

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: Pilot scale system development and installation **Budget: $ 407,363**

We will build 2 digestion reactors, 1 struvite precipitation reactor, 1 fermentation reactor, gas scrubber systems, and one air plasma for ammonia synthesis. Costs include all parts and labor for the construction of the entire system needed for digestion, struvite recovery, and fermentation.

Outcome	Completion Date
Four 250-gallon reactors construction and system setup and one air plasma for ammonia synthesis	Oct. 31, 2018

Activity 2: Evaluation and optimization of system for best conditions of operation **Budget: $ 208,733**

In this activity, we will determine the best operation conditions for swine manure mixed with sugar beet waste only; for swine manure mixed with DDGs only, and swine manure mixed with cellulosic waste only, to produce hydrogen and methane gas, designer fertilizer, biodegradable polymers, and animal feed. We will also determine the ammonia production potential of all three different waste combinations.

Outcome	Completion Date
1. Production of hydrogen and methane gas	June 30, 2019
2. Production of a designer fertilizer	Dec. 31, 2019
3. Production of biodegradable polymers	June 30, 2019
4. Production of animal feed from non-sulfur purple bacteria biomass	June 30, 2019
5. Continue production of all of the above	June 30, 2022

Activity 3: Green house and Field trials to test the designer fertilizer **Budget: $ 332,554**

Starting in 2019 green house trials will be conducted to start the initial characterization of the designer fertilizer under controlled settings and to determine the fertilizer combinations to be tested in the field. In 2020 field studies will be conducted to evaluate the nutrient release characteristics of the designer fertilizer under field conditions and to identify the best recommendations needed for various cropping systems (e.g. corn, soybean, forages). Three years are needed to develop a good understanding of the short and medium term characteristics and effects of the fertilizer on crops and soils and how it performs in different regions of the state. Field trials will be conducted at the Long-Term Agricultural Research Network (LTARN) at Waseca, Lamberton, and Grand Rapids, MN.

Outcome	Completion Date
1. Recommendation on best use for the designer fertilizer produced	June 30, 2022

III. PROJECT STRATEGY

A. Project Team/Partners

Paid by the project:

Project Leader: Paulo Pagliari, Assistant Professor in the Department of Soil Water and Climate, University of Minnesota. Dr. Pagliari will be responsible for overseeing the whole project.

Partners: Mr. Shaobo Deng, Lee Klossner, *technical support at Waseca and Grand Rapids to be determined*

In-kind contribution:

Dr. Forrest Izuno, Dr. Gregg Johnson.

B. Timeline Requirements (4 years)

Four years will be needed to complete this project. A year to 18 months will be needed for optimum operation to be determined. Three years of field research will be needed to determine the performance of the newly developed designer fertilizer and its potential as a crop fertilizer.

C. Long-Term Strategy and Future Funding Needs

The long-term strategy is to promote the implementation of this technology among sugar beet, ethanol plants, and pig producers to protect the environment and conserve natural resources by generating renewable energy and a crop fertilizer. This will lead to 1) the long-term win-win situation for the swine and sugar beet/ethanol industries; 2) production of bioenergy and fertilizer from renewable resources to move Minnesota into a leading position in the nation in environmentally friendly agriculture; and 3) new information about the “waste-to-product” concept for a broad audience so that the goal of achieving a “green economy” in Minnesota will be embraced by all Minnesotans.

2018 Detailed Project Budget

Project Title: *Converting Agricultural Wastes into Energy, Polymers, and Fertilizers*

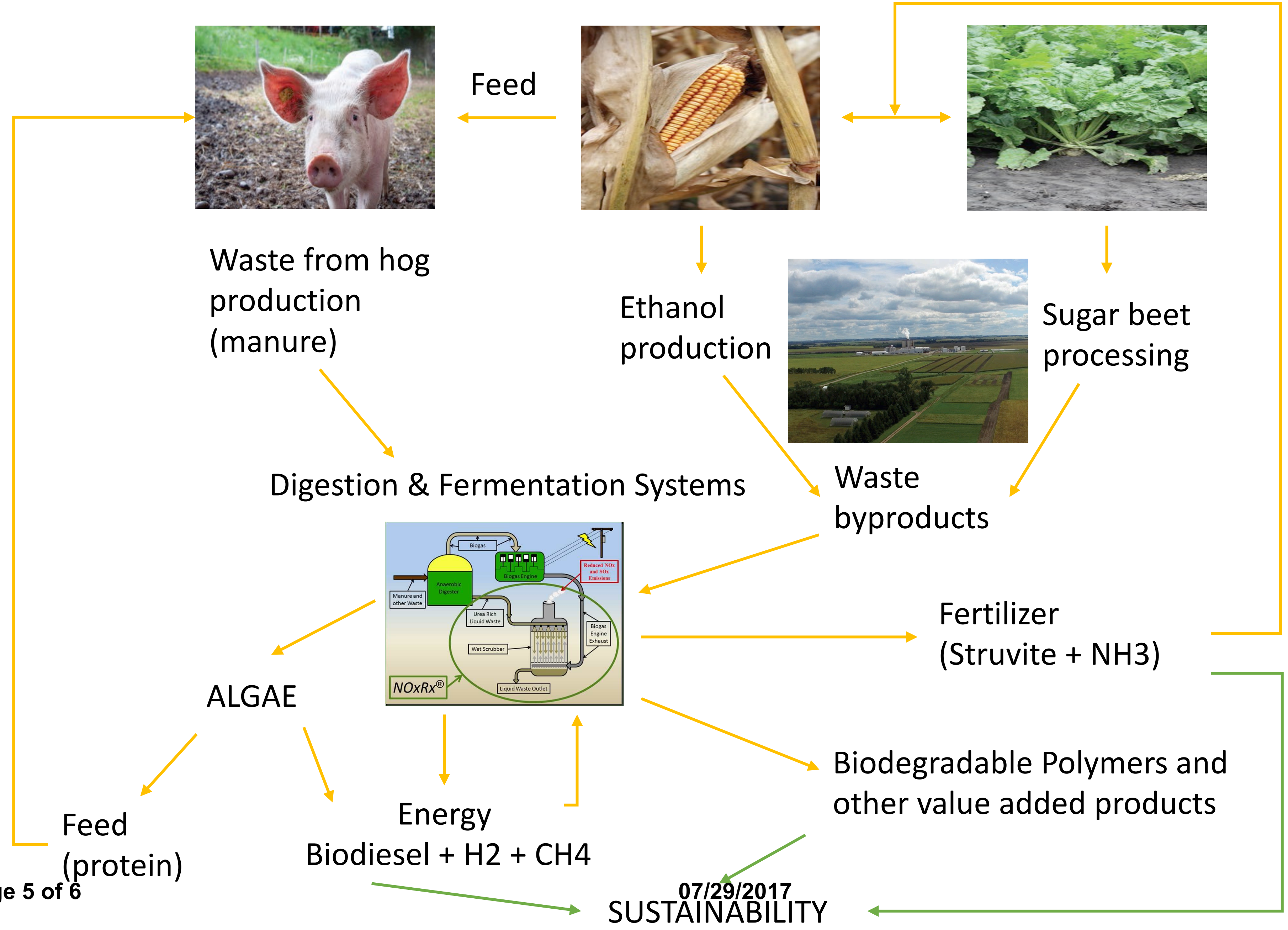
IV. TOTAL ENRTF REQUEST BUDGET 4 years

BUDGET ITEM	AMOUNT
Personnel: A 0.75 FTE Research Associate/Fellow, Project Manager: $240,840 (75% salary, 25% benefits) for each year. The research associate/Fellow will be the PM of this project overseeing the entire project with responsibility in all aspects including developing test protocols, conducting experiments, and preparing materials for publications and information dissemination.	$ 240,840
0.15 FTE for faculty to oversee the field trials and struvite fertilizer technolodgy development. $68,409 for all four years	$ 68,409
Research technicians $232,831 (73% salary and 27% benefits). 1.5 FTE (0.5 FTE at each lcoation where field trials will be conducted) will be responsible for conducting all of the trials related testing struvite and its components in all three years of the green house and field trial	$ 232,831
Field trial costs including: fees, sample analysis for field samples including soil fertility, biomass quality, carbon content $25,000 per location. $75,000 for all three locations all three years	$ 75,000
Sample analysis and data processing costs including 400 gas samples for hydrogen, methane and carbon dioxide content analysis ($60 each) and 500 liquid samples for COD, BOD, nitrogen, phosphorus, solids level and VFA tests ($60 each): $54,000.	$ 54,000
Purchasing parts and component for constructing all the reactors and systems including hydrogen fermenter, methane digester, biogas cleaning scrubber, struvite reactor and the size-adjusted integration system with all the control systems including reactor bodies, pumps, mixers, temperature and pH controllers, etc.: $80,000 one time cost.	$ 80,000
Purchasing parts and component for constructing the ammonia reactor system. $150,000 one time purchase.	$ 150,000
lab supplies: chemicals, tools glassware, gloves: $40,000	$ 40,000
Travel: mileage, lodging, meals for travel to and from sugar processing facilities and swine farms for substrates collection and data gathering. 4,000 miles per year at 0.535 mile, total $2,140 per year and $6,420 for three years. $1,500 for lodging and meals for all four years	$ 7,920
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 949,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period	*NA*	*NA*
Other State $ To Be Applied To Project During Project Period:	*NA*	*NA*
In-kind Services To Be Applied To Project During Project Period:	*NA*	*NA*
Past and Current ENRTF Appropriation: Clean water/renewable energy from beet waster/ manure. Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 08f	*400,000*	*06/2014-06/2017*
Other Funding History:	*NA*	*NA*

Sustainable and Value added Agricultural System



PAULO H. PAGLIARI
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Dr. Paulo Pagliari has a PhD. in soil science with emphasis on phosphorus management and soil fertility from the University of Wisconsin-Madison (UW-Madison), and M.S. degree in soil science at the University of Minnesota, and a BS degree in agronomy from the Maringa State University in Brazil. During his PhD. research, Dr. Pagliari became very familiar with newly developed techniques used to determine and quantify the amounts of bioavailable phosphorus (P) in animal manure and how they affected the different P pools in soils.

After graduating from the UW-Madison Dr. Pagliari had a one-year post-doc appointment at the southwest research and outreach center (SWROC) at the University of Minnesota and in 2012 he was hired as a tenure-track faculty. In his current appointment Dr. Pagliari is responsible for the development of innovative research to improve the knowledge on nutrient management in organic and conventional agricultural cropping systems. His focus has been primarily around soil P behavior, movement, transport, and cycling. In his research, Dr. Pagliari has been using newly developed methods and also developing new methods to better understand the role of organic P cycling on the availability of P from soils.

Selected peer reviewed publications include:

Schmitt, D., P.H. Pagliari, and C.A.C do Nascimento. 2017. Chemical distribution of phosphorus in soils used during the development of sorption isotherms. Soil Sci. Soc. Am. J. 81:84-93.

Zhongqi, H.E., P.H. Pagliari, and H.M Waldrip. 2016. Aplied and environmental chemistry of animal manure: a review. Pedosphere. 26:779-816.

Sakurada, L., M.A. Batista, T.T. Inoue, A.S. Muniz, and P.H. Pagliari. 2016. Organomineral Phosphate Fertilizers: Agronomic Efficiency and Residual Effect on Initial Corn Development. Agro J. 108:2050-2059.

do Nascimento, C.A.C., P.H. Pagliari, D. Schmitt, Z. He, and H. Waldrip. 2015. Phosphorus concentrations in sequentially fractionated soil samples as affected by digestion methods. Scientific Reports 5: 17967.

Waldrip, H.M., P.H. Pagliari, Z. He, R.D. Harmel, N.A. Cole, and M. Zhang. 2015. Legacy phosphorus in calcareous soils: Effects of long-term poultry litter application. Soil Sci. Soc. Am. J. 79: 1601-1614.

Pagliari, P.H. and C.A.M. Laboski. 2014. Effects of manure inorganic and enzymatically hydrolysable P on soil test phosphorus. Soil Sci. Soc. Am. J. 78:1301-1309.

The SWROC is one of 10 research centers at the University of Minnesota and provides local growers with current research based knowledge regarding best management practices for various cropping systems. Dr. Pagliari has a fully equipped laboratory where he conducts all of the chemical analysis needed for the success of his research program.