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

Project Title: **ENRTF ID:** **057-B**

Reducing Dairy Plant Impact on Water Quality

Category: B. Water Resources

Total Project Budget: $ 499,733

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

Summary:

Cheese whey disposed of by land application leads to water contamination by run-off. This project demonstrates how simultaneously treating the waste can simultaneously produce clean water and valuable food ingredients.

Name: Matt Julius

Sponsoring Organization: St. Cloud State University

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Summary of the current state of whey disposal vs. the proposed process. The proposed process digests cheese whey anaerobically, then CO2 and the digestate are metabolized by algal cultures to simultaneously produce clean water and valuable food ingredients. This makes this process an economically attractive way to process whey in an environmentally beneficial manner.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage		_____ TOTAL

PROJECT TITLE: Reducing dairy plant impact on water quality

I. PROJECT STATEMENT

Agricultural products such as cheese are a major revenue stream in rural Minnesota. Unfortunately, cheese production produces a liquid waste stream, which is high in nitrogen (of which a portion is converted to nitrites and nitrates), sodium, chloride and phosphorous. The waste stream (whey) accounts for approximately 90% of the volume of the milk used to make cheese. Land-application of untreated whey is common with small or specialty cheese producers, and the state allows this under its "*Permit to Land Apply Industrial Food By-products*". This leads to run-off that impacts surface and ground water. The goal of this project is to demonstrate a process that results in clean water from whey disposal, yet is also economically attractive enough to achieve widespread adoption due to the generation of valuable food ingredients. Our process:

- Uses a methane bioreactor to digest the whey
- **Captures the greenhouse gasses** from the methane production (85% of the CO2 and 95% of the hydrogen sulfide)
- Injects the CO2 and H2S into digestate from a methane reactor (which also contains sodium, chloride and phosphorous) where algae **will biometabolize phosphorus, nitrogen, and CO2 while simultaneously reducing sodium and chloride.**
- Metabolizes the remaining nutrients in a photo-bioreactor (PBR) and create high value food ingredients such as omega-3 fatty acids and carotenoid pigments by algae
- Harvests of the algae biomass from the now clean water, and extracts the high-value ingredients that will make this process economically attractive

The immediate outcome of the proposed study is the construction and deployment of a mobile demonstration unit of the system. Dr. Julius of SCSU has been instrumental in installing such a system for potato waste processing. The proposed system will be installed on two trailers and a shipping container to allow transport, and will be tested at multiple cheese plants. Dr. Schoenfuss is a food chemist and will evaluate the final water quality, and will extract and quantify the valuable ingredients in her lab at the University of Minnesota**.** An economic assessment will be conducted by a dairy applied economist, Marin Bozic, to demonstrate the feasibility of this system to encourage investment by the food industry. Both Schoenfuss and Bozic are associate directors of the Midwest Dairy Foods Research Center, and will be able to share the outcomes of this research with the dairy foods industry to promote its adoption. This mobile unit will be housed at St. Cloud State University at the termination of the study and can be deployed at other food processing operations or at events such as the State Fair to demonstrate the process and encourage adoption by Ag and food industries. The long-term vision is to demonstrate that treating food waste-water at the factory source, rather than land spreading, will both improve water quality and generate valuable, nutritious food ingredients.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Construction and deployment of the bioreactor demonstration unit to produce clean water and capture valuable bioactive products from cheese whey **Budget: $302,600**

To demonstrate the efficiency of the small-scale water treatment and bio-products production system, a demonstration trailer will be constructed which includes a methane bio-reactor, de-waterer, CO2/SO2 capture and infusion device, and a system to collect bio-products. Three artisan cheese manufacturers will be recruited to participate in the deployment and will have the demonstration system on-site for 3 months where they will process their cheese whey through the system. Cheese plants will be selected to represent 3 different types of cheese production which affect whey properties; acid whey, sweet whey, and whey from blue veined cheese

manufacturing. Research staff will monitor the unit and collect samples of whey, processed water and all of the bioproduct throughout the study period for further analysis.

Outcome	Completion Date
1. Completion of construction of the PBR Demonstration system	May 30, 2016
2. Deployment I	Aug 30, 2016
3. Deployment II & III	Aug 30, 2017

Activity 2: Evaluate cheese whey composition, finished water quality, and extract and quantify the ingredient produced by the algae **Budget: $191,473**

The composition of cheese whey varies depending on the cheese it is manufactured from. Acid whey has more lactic acid, calcium and phosphate, and blue veined cheese whey has higher added salt and more hydrolyzed ingredients. Understanding the effect of this whey on the ideal algae strain to be used will maximize water cleanup and ingredient yield by the algae.

Outcome	Completion Date
1. Analysis of whey, water after treatment and bioproduct from Deployment I	January 30, 2017
2. Analysis of whey, water after treatment and bioproduct from Deployment II & III	January 30, 2018
3. Yield calculations for ingredients generated by algae from all deployments	June 30, 2018

Activity 3: Evaluate the economic feasibility of whey processing by the proposed method to generate clean water and high-value food ingredients **Budget: $5660**

The ability of digestion to produce methane followed by high-value food ingredient production via algae is a new technology that has not been widely adopted due to the uncertainties of the economic payback. In some cases land-farming of whey or feeding to animals results in little direct cost to the cheese manufacturer, although there are environmental effects. This activity will evaluate the payback that can be achieved in terms of generating a profit center (the energy and bioproducts) that can be used to encourage processing of cheese whey to mitigate its environmental impact.

Outcome	Completion Date
1. Development of an economic analysis of the process	June 30, 2018

III. PROJECT STRATEGY

A. Project Team/Partners

Matt Julius, Professor, Department of Biological Sciences, St. Cloud State University, St. Cloud, MN – Co-PI, Algae (and their bioproduct production) Specialist Tonya Schoenfuss, Assistant Professor, Dairy Product Technologies, Department of Food Science and Nutrition, University of Minnesota, St. Paul, MN – Co-PI, Co-PI, Dairy Chemist and Dairy Industry Specialist

Marin Bozic, Assistant Professor, Dairy Foods Marketing Economics, Dept. of Applied Economics, University of Minnesota, St. Paul, MN – Collaborator, Applied Economist

B. Project Impact and Long-Term Strategy

The PBR Demonstration System created for this project would be housed at St. Cloud for further deployments, and for training and short-course opportunities for various industries interested in improving the composition of their waste water while generating valuable bioproducts. While this project focuses on smaller manufacturers who are not currently treating their waste, this concept could be expanded to larger facilities thereby reducing their impact on their current treatment and discharge processes. Facilities with existing methane bioreactors could benefit by the addition of a PBR to generate a value-added product, and further improve water quality.

C. Timeline Requirements

The proposed project will be completed in the allocated 3-year proposal period.

2015 Detailed Project Budget

Project Title: Reducing dairy plant impact on water quality

IV. TOTAL ENRTF REQUEST BUDGET $ 499,733 3 years

BUDGET ITEM	AMOUNT
Personnel:	$ -
Matthew Julius, Project Manager, Professor SCSU (65% salary, 35% fringe); 40 days over 2.5 years	21600
Tonya Schoenfuss, Co-PI, University of Minnesota (74.85% salary, 25.15%fringe); 8% FTE for 2.5 years	25,713
1 Graduate student assistant at the University of Minnesota to conduct and analyze experiments for 3 years. Salary (85%) + fringe (15%) including tuition, $13,510; = 50% FTE $36,920/year	110,760
Marin Bozic, Collaborator, Assistant Professor (84% salary, 16% fringe); 4% FTE for 1 year	5,660
Equipment/Tools/Supplies	
Anaerobic digester for biometabolizing whey products for energy production and preparation for algae production	150000
Gas polishing system to separate carbon dioxide and methane allowing methane to be returned to generator and carbon dioxide to be infused into the photobioreator media	15000
High speed centrifuge for algal biomass harvest	30000
Water purification and recycling system for photobioreactor	10000
Methane compatable generator for electricity production	20000
Photobioreactor for algal biomass production, nutrient fixing, and generation of high-value ingredient	50000
Supercritical fluid extractor for extracting bioproduct from algae biomass for quantification	25000
Supplies for compositional analysis of initial whey, fermentor digestate, bioproduct compostion and final water quality (protein, fat, ash, lipid composition, carotenoid pigments, phosphates and	30000
Travel:	$ -
Transport of the demonstration unit to 3 locations after manufacturing for deployments	5250
Travel of researchers to and from the deployment sites to monitor and maintain the system, andto collect products and componants	750
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 499,733

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period:	N/A	
Other State $ To Be Applied To Project During Project Period:	N/A	
In-kind Services To Be Applied To Project During Project Period: Unrecoverable IDC at 52% MTDC	$66,629	
Funding History:	N/A	
Remaining $ From Current ENRTF Appropriation:	N/A	

Proposed Innovation

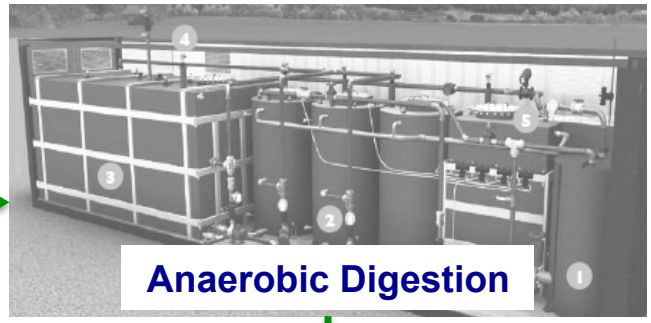
Cheese making generates nutrient-rich waste (whey)

Current Disposal Process of Whey

- Land applied
- Treat through sewer system

Results in:

Water pollution with nitrates, nitrites, phosphorous, sodium and chloride



- Anaerobic digestion of whey
- CO2 and H2S are captured
- Digestate is sent to the algae cultivation system

- Algae metabolize nutrients
- Algae produce either omega-3 fatty acids or carotenoid pigments
- Algae biomass is harvested from the now clean water and ingredients extracted

Extraction of High-Value Food Ingredient

Results in:

Clean water

High-value food-grade ingredient produced as a result of water purification

Project Manager Qualifications and Organization Description

Dr. Matt Julius, Project Manager
Professor, Department of Biological Sciences
St. Cloud State University

B.S., Biology, Butler University, Indianapolis, IN
M.S., Natural Resources and Environment, University of Michigan, Ann Arbor, MI
Ph.D., Natural Resources & Environment, University of Michigan, Ann Arbor, MI

Dr. Julius has been studying the aquatic ecology with particular emphasis to algae since 1993. His algal cultures, and knowledge of the development and deployment of bioreactor systems make him indispensible to this project. He is an author on over 16 peer-reviewed publications, all involving biological systems and the majority on algae. He has collaborated with industry partners who design methane digesters, and greenhouse gas capturing methods to combine with his self-designed photo-bioreactor to create the system that we are proposing. His knowledge of algae nutritional requirements, ability to maintain large, pure, stock cultures, and his knowledge of the primary production products are critical to this project to maximize success.

Tonya C. Schoenfuss, Co-PI
Assistant Professor, Department of Food Science and Nutrition, University of Minnesota

Dr. Schoenfuss has been studying dairy products, ingredients and analytical methods since 2008 at the University of Minnesota. Dr. Schoenfuss has already been involved in a MNTap waste mitigation project to reduce waste at a cheese plant in Melrose, MN. This ENRTF project would further her interest in reducing the impact of dairy product production by maximizing the capture of nutrients produced in the process. Her labs at University of Minnesota have the analytical capabilities to be able to analyze the whey at its different steps during the proposed remediation process. She collaborates with regional cheese and dairy product organizations and will provide the needed link to the industry partners for this project.

Dr. Marin Bozic, Collaborator
Assistant Professor in Dairy Foods Marketing Economics, Department of Applied Economics, University of Minnesota

Dr. Bozic's research program includes feasibility assessments of new dairy technologies, processing investments and new products. His involvement will provide the economic evaluation that will be necessary to justify adopting this mitigation strategy.

Organization Description
The University of Minnesota is the largest University in the state, and St. Cloud State University is the second largest. Both have extensive track records of supporting externally funded research. The laboratories and offices of the PI's and collaborators contain most of the necessary analytical equipment, with the exception of those requested in the proposal.