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

Project Title: **ENRTF ID: 050-B**

Linking Food, Energy, and Water for Resource Recovery

Category: B. Water Resources

Total Project Budget: $ 941,600

Proposed Project Time Period for the Funding Requested: 3 Years, July 2018 to June 2021

Summary:

Technological innovations will integrate the treatment of water from the food- and beverage-processing industry, energy generation, and greenhouse-based crop production for resource recovery, water conservation, and better water quality

Name: Paige Novak

Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The visual shows the linkages between process water treatment, energy generation, and crop production for resource recovery and clean water production

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

I. PROJECT STATEMENT

Our goal is to develop a system that will recover nutrients from food-processing water to grow greenhouse-based food crops and generate energy and clean water from what would otherwise be considered a waste. This innovation will lead to water quality and quantity benefits, resource recovery, and cost savings in both urban and rural Minnesota.

In Minnesota the food- and beverage-processing industry, including dairies, malting plants, and breweries, is vibrant and provides economic opportunities in both urban and rural communities. These industries are water intensive and discharge process water that contains nutrients and energy-rich compounds. A tremendous opportunity exists to treat the process water on-site using new, lower cost and low energy treatment technology that will actually generate energy for use by the food- and beverage-processing industry and recover nutrients from the process water for greenhouse-based food crop production. Such a system will save food- and beverage-processing industries money on process water treatment, facilitate resource (nutrient) recovery, provide an additional source of low-cost energy for use on-site, and provide an additional revenue stream via partnerships with greenhouse-based food crop producers. Such an integrated system will also save communities money on process water treatment and, through enabling water reuse and nutrient recovery, will provide water quality and quantity benefits. Our goal will be achieved by expanding previous LCCMR-funded research to:

- **Develop a robust, low-cost, point-of-use process water treatment system** to generate clean water and energy on-site,
- **Recover nutrients** in the process water through water reuse **via irrigation and fertilization of greenhouse-based food crops**, and
- **Generate targeted business plans and identify challenges and incentives** to the creation of integrated greenhouse-based food crop production and food- and beverage-processing.

Research will initially focus on the dairy and brewery industries, but will expand in the last year to include additional food- and beverage-processing industries.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Develop modular process water treatment technologies for energy and clean water production **Budget: $374,200**

Microbial encapsulation and a two-stage reactor design will be used for the development of a robust treatment system for process water from food- and beverage-processing industries that also enables onsite electricity generation. The system will be modular, customizable, and scalable.

Outcome	Completion Date
1. Treat process water from the dairy and brewery industries while simultaneously producing hydrogen and methane using encapsulated bacteria.	6/30/2020
2. Design a reactor that ensures robust system performance.	6/30/2020
3. Use an internal combustion engine-driven generator to burn the collected fuel for on-site electricity generation.	6/30/2021
4. Treat process water from additional food- and beverage-processing industries such as malting or sugar beet industries.	6/30/2021

Activity 2: Determine which food crops and greenhouse-based growing methods enable year-round high-intensity localized food production from treated process water **Budget: $333,300**

High value food crops amenable to greenhouse or warehouse hydroponic production with treated process water will be identified by quantifying plant growth rates in different treated water compositions. Additional water treatment that occurs during crop growth will be assessed.

Outcome	Completion Date
1. Determine which economically viable crops can be grown with treated process water from the dairy and brewery industries.	6/30/2020
2. Assess different hydroponic substrates and plants with respect to the removal of elements/nutrients from the process water during crop growth.	6/30/2020
3. Determine whether crops can also thrive in the presence of treated process water from additional food- and beverage-processing industries.	6/30/2021
4. Determine whether additional water treatment is required prior to discharge.	6/30/2021

Activity 3: Identify the barriers to the implementation of the integrated system and develop a strong business plan for success **Budget: $234,100**

The needs and potential for adoption of the technology will be explored though a product design team of engineering and business students. Engagement with project partners and pilot testing will reveal benefits of and challenges to implementation. Local and state-level public policies that challenge or support the creation of this kind of integrated system will be identified.

Outcome	Completion Date
1. Design product prototypes for commercial use and generate "voice-of-the-customer" data, a patent search, a market segmentation analysis, and a business plan.	6/30/2021
2. Investigate the complex policy interactions of the integrated system, including the legal feasibility and financial viability in different localities.	6/30/2021

III. PROJECT STRATEGY

A. Project Team/Partners: Minnesota has substantial motivation for greenhouse-based crop production, particularly in winter months. The state is also home to numerous food-based industries (*e.g.*, dairies, breweries, fruit/vegetable canning, malting plants) that are water-intensive and generate process water with a high carbon/energy and nutrient content. Project partners include:

- Fulton Brewery (will provide process water and space for pilot-scale testing)
- The University of Minnesota Dairy Lab (will provide process water and space for pilot-scale testing), and
- The Bemidji Food Shelf (has a farm and a 'deep winter' passive solar greenhouse; will work with us to explore the prototyping of our system).

Our team has been assembled to include expertise from the University of Minnesota in:

- Water treatment/energy (Novak and Arnold -Civil, Environmental, and Geo- Engineering; Aksan and Northrop-Mechanical Engineering),
- Intensive agriculture/hydroponic production systems in greenhouses and warehouses (Andersen, Grossman, Rogers-Horticulture Science), and
- Business, marketing and policy for the adoption of innovative solutions (Forbes-Carlson School of Management; Kelley-Humphrey School; Yue-Horticulture Science).

B. Project Impact and Long-Term Strategy: The benefit of this project to Minnesota is sustainable water and energy use, lower industrial costs, and innovative food production. It should also result in new marketing and business approaches to make this integrated system a reality. This research is also expected to promote the development of new businesses and/or augment existing business portfolios in the greenhouse-based crop production, water treatment, and renewable electricity areas. The work will also provide direction on how to optimize policies and/or regulations to encourage innovation at the nexus of food, water, and energy.

C. Timeline Requirements: Given the technical challenges and large experimental matrix, the project will require three years.

2018 Detailed Project Budget

Project Title: ***LINKING FOOD, ENERGY, AND WATER FOR RESOURCE RECOVERY***

IV. TOTAL ENRTF REQUEST BUDGET *3* years

BUDGET ITEM	AMOUNT
Personnel:	$ 747,583.00
Paige Novak, PI ($17,386 salary, 33.5% fringe rate; total for 3 years; 5.6% effort (2.8% paid), totaling $23,211). As the PI, Novak will oversee all aspects of the project as well as offering her technical expertise on Activity 1.	
Alptekin Aksan, Co-PI ($12,750 salary, 33.5% fringe rate; total for 3 years; 2.8% effort (paid); totaling $17,021). Aksan will be involved in Activity 1 and co-supervise one graduate student and the postdoctoral researcher.	
William Arnold, Co-PI ($17,386 salary, 33.5% fringe rate; total for 3 years; 2.8% effort (paid); totaling $23,211). Arnold will be involved in Activity 1 and co-supervise one graduate student and the postdoctoral researcher.	
Daniel Forbes, Co-PI ($16,923 salary, 33.5% fringe rate; total for 3 years; 2.8% effort (paid); totaling $22,592. Forbes will be involved in Activity 3 and co-supervise one graduate student and the business/engineering teams.	
Julie Grossman, Co-PI ($10,664 salary, 33.5% fringe rate; total for 3 years; 2.8% effort (paid); totaling $14,236). Grossman will be involved in Activity 2 and co-supervise one graduate student and the postdoctoral researcher.	
Steve Kelley, Co-PI ($16,523 salary, 33.5% fringe rate; total for 3 years; 7.5% effort (paid); totaling $22,058). Kelley will be involved in Activity 3 and co-supervise one graduate student.	
William Northrop, Co-PI ($12,055 salary, 33.5% fringe rate; total for 3 years; 2.8% effort (paid); totaling $16,093). Northrop will be involved in Activity 1 and co-supervise one graduate student and the postdoctoral researcher.	
Mary Rogers, Co-PI ($9,273 salary, 33.5% fringe rate; total for 3 years; 2.8% effort (paid); totaling $12,379). Rogers will be involved in Activity 2 and co-supervise one graduate student and the postdoctoral researcher.	
Note: Anderson and Yue will also provide guidance on the agricultural/crop and marketing portions of the project but do not need summer financial support. T**he team expertise is deep and broad, as described in the qualifications document. The various co-PIs are experts in complementary areas and will all offer technical guidance to the students and postdoctoral researcher involved in the project, providing an extremely well-qualified leadership team that will ensure successful completion of the proposed research.**	
One Postdoctoral Researcher ($144,400 salary, $30,902 fringe (includes healthcare); total for 3 years; providing overall project integration and working closely with both the agricultural/crop graduate student and wastewater treatment/energy generation graduate student).	
Three Graduate Research Assistants ($243,199 salary, $178,282 fringe (includes healthcare and tuition); total for 3 years for each student; one student will perform research on wastewater treatment/energy generation, one will perform research on crop selection/agricultural production, and the final graduate student will perform research on the policy and marketing challenges for an integrated system))	
Equipment/Tools/Supplies: Laboratory supplies and analytical costs (includes, but is not limited to, chemicals for all analyses, supplies to maintain analytical equipment, supplies for reactor construction, pumps, seeds, analytical fees), space rental costs for greenhouse studies, also marketing survey costs, and publication fees ($30,000/3 years)). These are all required and standard costs.	$ 160,000
Travel: Travel costs for sample collection, pilot system analysis, and meetings with partners in Bemidji.	$ 9,017
Additional Budget Items: Costs to develop the business plans, perform a patent search and market segmentation analysis with teams of business and engineering students.	$ 25,000
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 941,600

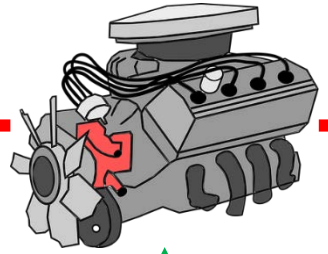
V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: none.	$ -	
Other State $ To Be Applied To Project During Project Period: none.	$ -	
In-kind Services During Project Period: Novak will contribute additional unpaid time on the project (2.8% or $23,211 total). Because the project is overhead-free, laboratory space, electricity, and other overhead costs are provided in kind. The University of Minnesota overhead rate is 54%	$ 456,200	Estimated (approximate)
Past and Current ENRTF Appropriation: to Novak and Arnold; M.L. 2013, Chp. 52, Sec. 2, Subd. 05g; $246,000 the first year is from the trust fund to the Board of Regents of the University of Minnesota to develop, optimize, and test membranes made of thin film polymers embedded with selected bacteria to generate clean water and energy in the form of hydrogen from wastewater. This	$ 246,000	Completed
Other Funding History: The PIs have been suppored by various internal University of Minnesota grants to begin this work; portions of this project have also been sponsored by the Minnesota Department of Commerce.	$ 305,000	Estimated

Onsite water treatment from food-based industries will lead to clean water, energy production, resource recovery, and locally grown food

Food processing industry

electricity



electricity

Hydroponic crop production

Hydrogen and methane fuels

Untreated process water

bioreactor

Treated water, optimal nutrients

market products

market products

Outcomes

- New treatment technology
- Clean water
- Energy production

Benefits

- Water Reuse
- Local Food Production
- Resource Recovery

Project Manager Qualifications and Organization Description

Paige J. Novak
Professor and Joseph T. and Rose S. Ling Chair of Environmental Engineering, Department of Civil, Environmental, and Geo- Engineering, University of Minnesota

B.S., Chemical Engineering, 1992, The University of Virginia, Charlottesville, VA.
M.S., Environmental Engineering, 1994, The University of Iowa, Iowa City, IA.
Ph.D., Environmental Engineering, 1997, The University of Iowa, Iowa City, IA.

Dr. Paige Novak will be responsible for overall project coordination. She has been studying the biological treatment of water and wastewater for over 20 years. Recent work has focused on the generation of energy from high-strength wastewater and the degradation of pollutants in wastewater to facilitate water reuse. She and Dr. William Arnold completed an LCCMR-funded project on the generation of energy from high-strength wastewater and obtained a patent, have submitted two additional patent applications with Alptekin Aksan, and have published a high-profile paper on that work.

Alptekin Aksan (Associate Professor, Mechanical Engineering) has expertise in the encapsulation of bacteria to create technologies capable of treating contaminants and producing products of value.

Neil Anderson (Professor, Horticultural Science) is an expert in aquaponics and hydroponics in northern greenhouse and warehouse systems, scheduling food crops, and the development of perennial crops with winter hardiness.

William Arnold (Distinguished McKnight University and Joseph T. and Rose S. Ling Professor, Civil, Environmental and Geo- Engineering) is an expert in chemical fate, transport, and water treatment.

Daniel Forbes (Associate Professor, Carlson School of Management) explores the development of and decision making in new business ventures and has expertise in entrepreneurship.

Julie Grossman (Associate Professor, Horticultural Science) develops ways to develop sustainable food production systems by managing nutrients in soils.

Steven Kelley (Senior Fellow, Humphrey School) has expertise at the intersection of policy, energy, and the environment. He served in MN House of Representatives from 1993-96 and the MN Senate from 1997-2006.

William Northrup (Richard and Barbara Nelson Assistant Professor and McKnight Land-Grant Professor, Mechanical Engineering) is an expert in combustion processes and sustainable energy technologies.

Mary Rogers (Assistant Professor, Horticultural Science) has expertise in sustainable production practices for fruit and vegetables in urban agriculture settings.

Chengyan Yue (Associate Professor, Bachman Endowed Chair in Horticultural Marketing, Horticultural Science and Applied Economics) specializes in exploring the market potential and consumer preferences for crops.

Organization Description
The University of Minnesota is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). The laboratories and offices of the PI and co-PIs contain all of the necessary fixed and moveable equipment and facilities needed for the proposed studies.