Environment and Natural Resources Trust Fund
2020 Request for Proposals (RFP)

Project Title: **ENRTF ID: 194-E**

Minnesota Shrimp Production Using Clean Energy

Category: E. Air Quality, Climate Change, and Renewable Energy

Sub-Category:

Total Project Budget: $ 1,129,000

Proposed Project Time Period for the Funding Requested: June 30, 2023 (3 yrs)

Summary:

We propose to develop a modularized shrimp production system that can utilize solar thermal, solar PV, and energy storage to power the energy-intensive process; providing fresh seafood to Minnesota.

Name: Robert Gardner

Sponsoring Organization: U of MN

Job Title: Dr.

Department: West Central Research and Outreach Center

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

We propose to develop an ecologically-sound, modularized shrimp production system. The system will utilize solar thermal, solar PV and energy storage to power the energy-intensive process.

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

PROJECT TITLE: Minnesota Shrimp Production Using Clean Energy

I. PROJECT STATEMENT

We propose to develop a modular shrimp production system using integrated solar thermal, solar electric, and energy storage systems to drive the production process. Minnesotans enjoy a diverse selection of seafood in our diets whether locally-caught fresh walleye, salmon, Maine lobster, or gulf coast shrimp. Many types of seafood travel from locations across the globe to reach Minnesota. This impacts food quality and safety but also the energy and carbon footprint of the food we eat. One option is to raise seafood locally. This can be done by creating a climate conducive to raising various species of fish and crustaceans. However, energy consumed in creating this artificial climate can be significant. For example, shrimp require a constant 95^{O} F water temperature and water filtration throughout production. A commercially-available solar thermal system can be designed to heat water for year-long shrimp production. A typical barrier for solar thermal systems in Minnesota is the lack of a consistent use for the hot water (e.g. winter versus summer load). Shrimp production appears to be a good match considering the need for a consistent source of warm water yearlong. Solar PV paired with a battery can also provide the electrical energy needed to recirculate and filter the water. We envision a modular, shipping container shrimp production system that can be set on a prepared surface. The shipping containers are natural platforms for solar thermal and solar PV systems. The modular configuration will allow for production systems that are sized to meet local demand for fresh, locally raised shrimp. Benefits of a successful project include:

- Increased utilization of local renewable energy resources,
- Renewable generation matched with new energy loads lowering impact to electric utilities,
- Contained environment virtually eliminating ecological impact of commercial seafood production,
- Distributed, local food production across the state providing fresh seafood,
- New business opportunities and markets for Minnesota farmers,
- Development of a technology platform that can be manufactured in Minnesota, and
- Increased economic development opportunities in Greater Minnesota.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Design and develop a modular shrimp production system using solar energy systems.
Description: A modular shrimp production system will be designed using a modified shipping container. The project team will work with an engineering firm to develop the design. A 40-foot shipping container equipped with electric service, lights, and HVAC system for conditioning the room temperature will be purchased. The container will be delivered to the University of Minnesota West Central Research and Outreach Center (WCROC) near Morris, MN. The shipping container will be dropped on a level, prepared site with access to water, electricity, and fiber optics. Additional insulation will be added on-site. The modular container will contain four tanks for the shrimp – a nursery tank and three grower tanks. Water filtration systems and recirculation pumps will also be installed. Brackets will be installed on the south-facing exterior side as well as the roof to accommodate installation of solar thermal and solar photovoltaic panels. A heat exchanger, hot water storage tank, and pump will be installed to store solar thermal energy. A battery system will also be installed to store energy generated by the solar PV system. The intent is to have adequate solar energy capacity and storage to provide a majority of the energy load both day and night throughout the year. Finally, an internet enabled control and data acquisition system will be installed along with the accompanying control and data sensors and meters to measure water flow, temperature, pH, as well as air temperature and energy consumption. All necessary permits will be obtained. The modular production system will then be fully commissioned and tested prior to introducing shrimp. After completing three replicated trials of shrimp production, the system will be optimized and a second set of at least three replicated trials will be performed.

ENRTF BUDGET: $571,225

Outcome	Completion Date
1. Complete a design of a modular, shrimp production system incorporating solar energy and energy storage.	*11/01/2020*
2. Complete installation of a modular, shrimp production systems utilizing a modified shipping container with solar thermal and solar PV systems attached.	*07/01/2021*
3. Commission the modular, shrimp production system.	*08/01/2021*
4. Optimize the mechanical systems within the modular, shrimp production system.	*03/01/2022*

Activity 2: Field test a modular shrimp production system

Description: The modular shrimp production system, utilizing solar thermal and solar PV systems, will be field tested at the WCROC farm near Morris, MN. The tanks will be inoculated with beneficial bacteria and the water conditioned to appropriate levels. Shrimp feed will be sourced from domestic vendors. Juvenile shrimp or larvae will be purchased and raised within the nursery tank until they reach approximately one gram in weight and then will be transitioned to the grower tank(s). Then, the fast-growing shrimp will be introduced to one of three larger grower tanks within the modular building and raised to harvest weight at approximately six months. Upon harvest the shrimp will be weighed and processed. Variables measured will include total shrimp weight, feed efficiency, survival rate, water quantity and temperature, and energy production and consumption. Microbial populations, important for the growth of the shrimp, will be monitored throughout the nursery and grower phases. Three replicate grower trials will be completed and then the system will be re-evaluated and potentially re-configured to improve modular shrimp production. At least three additional replications will then be completed. Each replicate duration from the larvae stage to grower and grower to harvest is estimated to take 40 to 60 days depending on the target harvest weight. The target harvest weight may change during the study in order to optimize overall system production. A basic techno-economic assessment of the technology will be performed with results disseminated to Minnesota farmers through a various forms including the Midwest Farm Energy Conference and the WCROC web-site. A tech-to-market plan will be developed including options to pursue fabrication of the production system within Minnesota. A comprehensive final report will be submitted to the commission.

ENRTF BUDGET: $557,775

Outcome	Completion Date
1. Complete first shrimp production study and analyze results.	*01/01/2022*
2. Optimize the biological processes within the modular, shrimp production system.	*03/01/2022*
3. Complete second shrimp production study and analyze the results.	*03/01/2023*
4. Perform a basic techno-economic assessment of the modular production system.	*05/01/2023*
5. A technology-to-market plan will be developed.	*05/01/2023*
6. A comprehensive final report will be submitted to the commission.	*06/30/2023*

III. PROJECT PARTNERS AND COLLABORATORS: Professor Robert Gardner will lead this project. He has expertise in beneficial microbial production in water-based systems. Dr. Joel Tallaksen and Eric Buchanan have expertise in clean energy system development and analysis. Curtis Reese will oversee shrimp production having significant experience in aquaculture production systems. All participants are located at the WCROC.

IV. LONG-TERM IMPLEMENTATION AND FUNDING: A tech-to-market plan will developed. The plan will provide a pathway to commercialization. If successful, the system will be self-sustaining and new businesses created.

V. SEE ADDITIONAL PROPOSAL COMPONENTS: Including **A. Proposal Budget Spreadsheet, B. Visual Component, and F. Project Manager Qualifications and Organization Description.**

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Robert Gardner
Project Title: Minnesota Shrimp Production Using Clean Energy
Organization: University of Minnesota West Central Research and Outreach Center
Project Budget: $1,129,000
Project Length and Completion Date: Three years; June 30, 2023
Today's Date: April 15, 2020

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 604,733	$ -	$ 604,733
Prof. Robert Gardner, Project Mngr., $28,189 (%salary & %fringe) 2 mo. summer salary, 3 yrs.			
Graduate Student, $147,947 (58%salary and 42%fringe) 1 FTE, 3 yrs.			
Researcher 2, Data collection, $205,278 (77%salary and 23%fringe) 1 FTE, 3 yrs.			
Farm Manager, Shrimp production, $57,165 (77%salary & 23%fringe) 0.2 FTE, 3 yrs.			
Eric Buchanan, Energy system development, $47,938 (74%salary and 26%fringe) 0.2 FTE, 3 yrs.			
Joel Tallaksen, Energy data analysis, $106,216 (74%salary and 26%fringe) 0.4 FTE, 3 yrs.			
Undergraduate Student Intern, $12,000, two summers at $6,000 each year			
Professional/Technical/Service Contracts			
Shrimp Production Nutritionist Consultant ($9,000 per year - 3 years)	$ 27,000	$ -	$ 27,000
Mechanical and Electrical Engineering Design Consultant ($18,000 per year - 2 years)	$ 36,000	$ -	$ 36,000
Mechanical and Electrical Installation Contractor	$ 45,000	$ -	$ 45,000
Equipment/Tools/Supplies			
Juvenile shrimp (Six 22,000 count units @ $3,300 each)	$ 19,800	$ -	$ 19,800
Shrimp feed, bacteria, and brine ($0.35 / lb * 16,000 lbs * 6 feeding trials)	$ 33,600	$ -	$ 33,600
Water testing sensors and supplies	$ 8,000	$ -	$ 8,000
Netting, bags, pails, etc for care, data collection, transfer, and harvest	$ 5,400	$ -	$ 5,400
Scale for data collection	$ 1,705	$ -	$ 1,705
Automatic feeders (8 @ $250 each)	$ 2,000	$ -	$ 2,000
Shrimp production tanks (4 @ $1,500 each)	$ 6,000	$ -	$ 6,000
Capital Expenditures Over $5,000			
Modified, 40 foot shipping container with HVAC system including delivery and site prep	$ 195,000	$ -	$ 195,000
10 kW Solar PV system including installation ($3 / watt x 10,000 watts)	$ 30,000	$ -	$ 30,000
Battery pack and control system	$ 15,000	$ -	$ 15,000
Solar thermal system	$ 16,000	$ -	$ 16,000
Water filtration and circulation system	$ 12,000	$ -	$ 12,000
Data acquisition and control system	$ 26,000	$ -	$ 26,000
Printing			
Brochures for the Midwest Farm Energy Conference (6,000 copies x $1)	$ 6,000	$ -	$ 6,000
Handouts for the Midwest Farm Energy Conference (est. 30 pages X 150 people x $0.12 / copy)	$ 540	$ -	$ 540
Printing of project results in public-friendly form (400 copies X $15)	$ 6,000	$ -	$ 6,000
Travel expenses in Minnesota			
Project team travel to meetings in Minnesota (4 mtgs per year, 313 miles ea @ $.58/mile)	$ 2,178	$ -	$ 2,178
Travel to disseminate results in MN (4 /yr, 313 miles ea @$.58/mi., 1 night lodging ea, 4 meals ea)	$ 4,344	$ -	$ 4,344
Other			
Mass spectrometer annual service fee for sample analysis ($8,000 per year)	$ 24,000	$ -	$ 24,000
Postage for advertizing the Midwest Farm Energy Conference (6,000 pieces x $0.45)	$ 2,700	$ -	$ 2,700
COLUMN TOTAL	$ 1,129,000	$ -	$ 1,129,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State: NA	NA	$ -	$ -	$ -
State: NA	NA	$ -	$ -	$ -
In kind: Match in lieu of indirect cost recovery	Pending	$ 404,563	$ -	$ 404,563

Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
ML 2014 Ch 312 Sec 8 Subd 08d Transitioning MN Farms to Local Energy		$ 500,000	$ 500,000	$ -
ML 2016 Ch 186 Sec 2 Subd 07d Utilization of Dairy Farm Wastewater		$ 475,000	$ 397,000	$ 78,000
ML 2016 Ch 186 Sec 2 Subd 07e Solar Energy Utilization for MN Swine Farms		$ 475,000	$ 432,000	$ 43,000
ML 2017 Ch 96 Sec 2 Subd 07c Generation, Storage, and Utilization of Solar Energy		$ 500,000	$ 336,000	$ 164,000
ML 2018 Ch 214 Art 4 Sec 2 Subd 08d Ag Weed Control Using Autonomous Mowers		$ 750,000	$ 18,000	$ 732,000

We propose to develop an ecologically-sound, modularized shrimp production system. The system will utilize solar thermal, solar electric, and energy storage systems integrated into a large shipping container. The seafood farming industry utilizes significant amounts of energy. The system we envision can efficiently use local, renewable energy resources and be sized to match markets across Minnesota.

Energy Storage

Solar Thermal Energy

Solar Electric Energy

Photo by Nathan Clymer

Benefits include:

- Increased utilization of local renewable energy resources,
- Renewable generation matched with new energy loads lowering impact to electric utilities,
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F. Project Manager Qualifications and Organizational Description

Robert Gardner, Principle Investigator and Project Manager:

Dr. Gardner is an Assistant Professor of Renewable Energy at the University of Minnesota West Central Research and Outreach Center and has a Ph.D. in Chemical Engineering from Montana State University. Dr. Gardner's research focuses on the interface between microbiology and chemical engineering. Microbes have naturally evolved through adaptation to their respective niche environments, and thus developed unique metabolic processes that can be utilized for production applications. Examples include the use of photosynthetic microbes for bioenergy production or anaerobes for bioremediation of toxic chemicals. This is an interdisciplinary area of research. However, microbial processes are controlled at a fundamental level by mass and energy balances, thermodynamics, mass transport and chemical reaction kinetics, and these topics are at the core of bioproducts and biosystems engineering -- especially since microorganisms (single species or complex communities) have unique and adaptive behavior that can manifest a diverse spectrum of responses, which is in contrast to most abiotic chemical engineering applications. Dr. Gardner's research strength is on elucidating fundamental microbial metabolic processes and strategically enhancing them for useful applications. These processes are very similar to shrimp production as it is necessary to manage beneficial microbial populations, water conditions, and provide adequate nutrients for efficient growth of shrimp. In addition to Dr. Gardner's research interests, he co-teaches one of the most popular on-line classes at the university titled BBE 2201 – Renewable Energy and the Environment to approximately 400 students per semester.

The West Central Research and Outreach Center (WCROC) is a century-old agricultural experiment station located near Morris, MN. The research facility consists of approximately 1,100 acres of pasture and farmland, administration office complex, grain and livestock facilities, and supporting research facilities. The WCROC also houses the regional extension office for western Minnesota. WCROC has five primary areas of research including Crop, Dairy, Horticulture, Swine, and Renewable Energy. Staff at the WCROC have significant experience in researching novel and complex agricultural production systems including organic crop and dairy production, alternative swine systems, and leading edge renewable energy systems such as nitrogen fertilizer production using renewable energy. Dr. Gardner leads the algal and other microbial production systems research at the WCROC. His research lab is located at the nearby USDA ARS North Central Soils Conservation Lab. The lab consists of analytical equipment including a mass spectrometer. The lab can perform a number of analysis related to identifying microbial populations, chemical assay, and characterization of minerals and other nutrients and waste products. Dr. Gardner's field experiments are conducted at the WCROC research farm where there is adequate space and support infrastructure. From a clean energy standpoint, the WCROC hosts a variety of energy production systems including a 1.65 MW Vestas V-82 wind turbine, two 10 kW wind turbines, an evacuated tube solar thermal system, two flat-plate solar thermal systems, and five solar PV systems totaling 131 kW.