

**Environment and Natural Resources Trust Fund**

# 2023 Request for Proposal

## **General Information**

**Proposal ID:** 2023-111

**Proposal Title:** Accelerating Biogas Production in Cold Climates

## **Project Manager Information**

**Name:** Daniel Bond

**Organization:** U of MN - College of Biological Sciences

**Office Telephone:** (651) 247-3805

**Email:** dbond@umn.edu

## **Project Basic Information**

**Project Summary:** This project will demonstrate that energy-rich biogas production from wastewater at cold temperatures could be possible using small solar-powered devices that directly aid microbial growth

**Funds Requested:** $399,000

**Proposed Project Completion:** June 30, 2026

**LCCMR Funding Category:** Air Quality, Climate Change, and Renewable Energy (E)

## **Project Location**

**What is the best scale for describing where your work will take place?** Statewide

**What is the best scale to describe the area impacted by your work?** Statewide

**When will the work impact occur?** In the Future

## **Narrative**

**Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.**

This proposal will test a new energy-saving technology that could speed up wastewater digestion in cold climates.

Hundreds of Minnesota treatment plants spend millions each year to inject oxygen into wastewater. This aerobic process supports rapid microbial growth, reducing treatment times to hours. While fast, it is expensive, and forfeits the bioenergy within the waste’s sugars and oils.

Larger municipalities, such as Hennepin County and the Western Lake Superior Sanitary District, can afford million-gallon scale fermentation chambers, and the $4.4 M/y Minnesota Bioincentive Program aids construction of such facilities. These ‘anaerobic digestors’ do not require oxygen injection, and instead produce valuable methane-rich biogas. Unfortunately, growth under anaerobic conditions is very slow, requiring months to break down wastes in large reactors. Because of this, cities such as Duluth invest extra energy, burning most of their biogas to heat reactors and speed up digestion.

We propose a new approach that could rapidly produce valuable biogas without adding heat: building tiny devices that float in reactors, using free solar energy to stimulate organisms directly in the water. This technology could be especially useful at smaller scales, such as pre-treating concentrated food-processing wastes that can overwhelm local facilities.

**What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.**

Our solution relies on a technology known as the ‘microbial fuel cell’. Bacteria common in iron-rich Minnesota naturally link metal transformations to organic material breakdown. In other words, these bacteria eat rust. Electrodes can mimic these metals, encouraging rapid microbial growth while capturing their metabolic output as useful electricity.

However, adding microbial fuel cells to anaerobic digestors requires large electrodes, complex voltage regulators, membranes, and batteries. Smaller microbial fuel cells are used commercially, but only to treat agricultural wastes in warm climates.

Miniaturization now makes it possible to get the stimulating benefit of microbial fuel cells, without added complexity or heat. We can mass-produce glass particles the size of algae, that contain functional solar cells. Light creates a voltage across the particles, creating a favorable environment that stimulates microbial fuel cell bacteria. This internal boost causes biogas to be produced much faster than any available solution. No external power source, monitoring, membrane, or energy is needed, and the particles are large enough for easy recovery by gravity.

Our proposed work will collect the first measurements of biogas production by these simplified solar devices in unheated wastewater, and test their durability over multiple uses.

**What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state’s natural resources?**

We will measure biogas production during solar-enhanced bacterial breakdown of wastewater. This is a new energy-producing technology most relevant to northern climates as it could accelerate biogas production without complex electronics or added heat. In industries such as beverage and food processing, waste with a high organic content is common. Pre-treatment by our method could lower energy costs and reduce the burden on existing Minnesota waste treatment facilities.

## **Activities and Milestones**

### **Activity 1: Test new solar particle designs for maximal microbial growth**

**Activity Budget:** $159,600

**Activity Description:**The first activity will identify optimal designs and produce useful quantities of robust solar cell particles.

The key to increasing performance is to identify the best conditions that stimulate the bacteria. We will measure growth of model microbes on particles powered by different sizes and numbers of solar cells. Preliminary experiments over the past two years suggest 1-2 panels per device, occupying about 25% of available space could be sufficient. We will then incubate samples of the best designs in reactors with decreasing amounts of illumination, with the goal of identifying the fastest gas production rates at <25% of normal sunlight intensity.

Following these experiments, our team will produce larger quantities of prototypes in three increasingly larger sizes. These will be used to test performance using model bacteria, testing which size is most easily recovered for reuse.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Design and test particle fabrication process | July 31, 2024 |
| Screen prototypes on-chip with test organisms | December 31, 2024 |
| Build free particle prototypes for tests with live bacteria | July 31, 2025 |

### **Activity 2: Identify high-performing solar particles with wastewater bacteria**

**Activity Budget:** $239,400

**Activity Description:**The second activity will focus on measuring biogas production by solar-powered particles using real anaerobic digestor bacteria, under cold conditions.

Every experiment will be compared to a non-illuminated control using the same bacteria. Experiments will begin by recovering bacteria from particles incubated with and without light reactors, and use rapid DNA sequencing to find which conditions successfully aid the desired microbial fuel cell bacteria. We will then incubate the best-performing particles while measuring biogas production, and conduct multiple cycles recovering and re-feeding particles to demonstrate reusability. Finally, we will conduct experiments with the best-performing designs at progressively colder temperatures, comparing gas production to standard anaerobic digestion.

**Activity Milestones:**

|  |  |
| --- | --- |
| **Description** | **Completion Date** |
| Demonstrate naturally-occurring wastewater bacteria grow on particles | July 31, 2025 |
| Compare cold temperature biogas production rates as a function of light and size | December 31, 2025 |
| Compare biogas production rates of particles to anaerobic digestion at cold temperatures | June 30, 2026 |

## **Project Partners and Collaborators**

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Organization** | **Role** | **Receiving Funds** |
| Joseph Talghader | University of Minnesota | Co-Investigator supervising design and fabrication of devices | Yes |

## **Long-Term Implementation and Funding**

**Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?**This project is designed to produce the first demonstration that, by simplifying the concept of the microbial fuel cell, energy recovery from wastewater can be accelerated dramatically. This will be of great interest to other engineers and researchers. If successful, we will pursue funding from the National Science Foundation and the Department of Energy to study how our invention could be scaled up and adapted for commercial use in other energy-intensive processes.

## **Other ENRTF Appropriations Awarded in the Last Six Years**

|  |  |  |
| --- | --- | --- |
| **Name** | **Appropriation** | **Amount Awarded** |
| Microbes for Salt and Metal Removal | M.L. 2016, Chp. 186, Sec. 2, Subd. 04o | $596,000 |

## **Project Manager and Organization Qualifications**

**Project Manager Name:** Daniel Bond

**Job Title:** Professor of Microbiology

**Provide description of the project manager’s qualifications to manage the proposed project.**The project manager has conducted research in water treatment, bioremediation, anaerobic digestion, and metal recovery for over 20 years. Since 2004, they have been a Professor of Microbiology and member of the BioTechnology Institute at the University of Minnesota. Relevant to this proposal, Dr. Bond was part of the original team that discovered bacteria could produce power using devices now known commercially as microbial fuel cells. Dr. Bond was project manager of a 2016 LCCMR project that focused on microbially-powered approaches for treating salt and metal contamination at the Soudan Iron Mine in Tower, MN.

**Organization:** U of MN - College of Biological Sciences

**Organization Description:**This project is a collaboration between the Colleges of Biological Science and College of Science and Engineering at the University of Minnesota, one of the largest and most prestigious public universities in the United States. The laboratories directed by the project managers house all equipment needed to conduct the project and provide unique undergraduate educational experiences. The University of Minnesota also is home to the MN Nano Center, a world-class facility for nanoscale fabrication which will be used by University researchers “at cost”.

## **Budget Summary**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category / Name** | **Subcategory or Type** | **Description** | **Purpose** | **Gen. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified Staff?** | **$ Amount** |
| **Personnel** |  |  |  |  |  |  |  |  |
| Daniel Bond |  | Project Manager |  |  | 25% | 0.15 |  | $28,443 |
| Joseph Talghader |  | Co-Investigator supervising micro fabrication |  |  | 25% | 0.15 |  | $39,048 |
| Graduate Students |  | Fabricate new devices and perform wastewater incubations |  |  | 46% | 2.49 |  | $254,405 |
|  |  |  |  |  |  |  | **Sub Total** | **$321,896** |
| **Contracts and Services** |  |  |  |  |  |  |  |  |
| Minnesota NanoFabrication Center | Internal services or fees (uncommon) | The MN NanoFabrication Center offers easy fee-for-service usage, removing the obstacles of capital equipment acquisition, maintenance costs, and long-term commitments. UMN faculty receive reduced academic use rates. |  |  |  | 0 |  | $33,615 |
|  |  |  |  |  |  |  | **Sub Total** | **$33,615** |
| **Equipment, Tools, and Supplies** |  |  |  |  |  |  |  |  |
|  | Tools and Supplies | Chemicals, molecular biology reagents, model reactors, and gas analysis supplies | To conduct experiments with prototype devices and collect data |  |  |  |  | $38,500 |
|  |  |  |  |  |  |  | **Sub Total** | **$38,500** |
| **Capital Expenditures** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Acquisitions and Stewardship** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel In Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Travel Outside Minnesota** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
| **Printing and Publication** |  |  |  |  |  |  |  |  |
|  | Publication | Open access publication charges | Publishing results in 'open access' journals allows any member of the public and LCCMR staff to access and use data without any future library or subscription charges. |  |  |  |  | $4,989 |
|  |  |  |  |  |  |  | **Sub Total** | **$4,989** |
| **Other Expenses** |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  | **Sub Total** | **-** |
|  |  |  |  |  |  |  | **Grand Total** | **$399,000** |

### **Classified Staff or Generally Ineligible Expenses**

|  |  |  |  |
| --- | --- | --- | --- |
| **Category/Name** | **Subcategory or Type** | **Description** | **Justification Ineligible Expense or Classified Staff Request** |

### **Non ENRTF Funds**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Category** | **Specific Source** | **Use** | **Status** | **Amount** |
| **State** |  |  |  |  |
| In-Kind | The University of Minnesota typically charges a 55% overhead rate for all research expenditures except for those on capital equipment and graduate student tuition. By law, the University of Minnesota does not charge this overhead on projects funded by the State of Minnesota. | Overhead | Secured | $174,019 |
|  |  |  | **State Sub Total** | **$174,019** |
| **Non-State** |  |  |  |  |
|  |  |  | **Non State Sub Total** | **-** |
|  |  |  | **Funds Total** | **$174,019** |

## **Attachments**

### **Required Attachments**

#### ***Visual Component***

File: [bb43019f-d7c.pdf](https://lccmrprojectmgmt.leg.mn/media/map/bb43019f-d7c.pdf)

#### ***Alternate Text for Visual Component***

Overview of how solar energy delivered directly to bacteria could accelerate production of energy-rich gas from wastewater compared to standard anaerobic digestion...

## **Administrative Use**

**Does your project include restoration or acquisition of land rights?**
 No

**Does your project have potential for royalties, copyrights, patents, or sale of products and assets?**
 Yes

**Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?**
 Yes

**Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?**
 No

**Does your project include original, hypothesis-driven research?**
 Yes

**Does the organization have a fiscal agent for this project?**
 Yes, Sponsored Projects Administration