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

**Project Title:** **ENRTF ID: 068-B**

Rural Wastewater Treatment: Water Reuse and Energy Production

**Category:** B. Water Resources

**Total Project Budget: $** 297,000

**Proposed Project Time Period for the Funding Requested:** 2 years, July 2018 to June 2020

**Summary:**

This project aims to develop a rural wastewater treatment system that could replace septic tanks, decreasing pollution entering rivers and lakes and increasing potential water reuse and energy generation.

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**Sponsoring Organization:** U of MN

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**Location**

**Region:** Statewide

**County Name:** Statewide

**City / Township:**

**Alternate Text for Visual:**

Visual representation of the proposed rural wastewater system

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

**PROJECT TITLE:** ***Rural wastewater treatment: water reuse and energy production***

## I. PROJECT STATEMENT

**This research aims to develop a new and more sustainable rural domestic primary sewage treatment to decrease pollution entering water bodies.** Management of rural wastewater mostly involves on-site treatment using septic systems. The septic systems consist of a septic tank followed by a soil percolation area. Conventional septic tanks treatment is limited since the system relies on the capacity of retaining suspended solids by accumulation and sedimentation. In addition, solids that settle undergo inefficient anaerobic digestion where most of the dissolved organics (soluble organic matter) and nutrients (nitrogen and phosphorous) are solubilized into the water phase as well as emit powerful green house gases (GHGs), such as methane ($CH_4$), nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$) to the atmosphere. While the tank decreases the suspended solids, the slow percolation of the effluent through the soil attenuates most of the nutrients, micro-pollutants, and pathogens that are present in household wastewater causing potential contamination of the nearby groundwater and surface water, which may have direct consequences for human and environmental health.

Anaerobic membrane technology has been recently introduced as an alternative technology to treat domestic wastewater. Anaerobic membranes bioreactors can achieve good quality effluents without particulates and pathogens, generate less sludge while producing renewable energy and potentially removing micro-pollutants. However, the main constraints of the membrane technology are related to membrane fouling, the high cost of the membranes and a relatively high energy consumption. **Recently, a new configuration, the gas-lift configuration, has been introduced as a more efficient and sustainable alternative. This low-pressure system combines the advantages of cross-flow and submerged configurations allowing high fluxes with lower energy requirements.** Yet, there is limited information about the application of low-pressure configuration for rural wastewaters. Minnesota has rural wastewater treatment challenges due to its cold climate. Low temperatures and temperature fluctuation affect the performance of any treatment system. **Thus, the specific aim of this project is to evaluate the feasibility of using gas-lift anaerobic membrane bioreactors for the treatment of rural domestic wastewater as an alternative for septic systems under Minnesota's environmental conditions.**

## II. PROJECT ACTIVITIES AND OUTCOMES

**Activity 1:** *Gas-lift bioreactor lab-scale set-up and operation using synthetic wastewater* **Budget: $120,000**

To evaluate the performance of the gas-lift anaerobic membrane bioreactor treating synthetic sewage, one lab-scale reactor will be designed, constructed and operated using synthetic wastewater under low temperature (15 ±2 °C). The reactor will consist of a high-rate anaerobic digester, i.e. an anaerobic Up-flow Anaerobic Sludge Blanket (UASB) reactor inoculated with granular sludge. The UASB reactor will be coupled with a commercially available low-pressure ultra-filtration membrane. The gas-lift shear will be created with biogas produced in the UASB reactor. During this activity, the operational parameters of the lab-scale reactor will be optimized in order to obtain the highest quality effluent, i.e. aiming for a removal of > 90% of carbon. In addition, the amount and quality of the biogas will be measured. The overall efficiency of the process will be determined in terms of carbon, nitrogen and phosphorous removal and biogas production. In addition, the microbial communities present in the reactor will be identified and correlated to operational parameters by using next generation sequencing tools. The bacterial community identification will provide information on which specific group of microorganisms are responsible for the removal of pollutants.

| Outcomes | Completion Date |
|---|---|
| *1. The design and construction of a lab-scale reactor.* | *09-01-2018* |
| *2. The identification of the best operational parameters for highest quality effluent.* | *12-01-2018* |
| *3. The identification of the bacterial communities present in the reactor.* | *01-15-2019* |

**Activity 2:** Gas-lift anaerobic membrane bioreactor *onsite installation and operation* **Budget: $142,000**
To demonstrate the feasibility of the developed gas-lift anaerobic membrane bioreactor treating real wastewater under Minnesota conditions, a site with a domestic wastewater source will be selected to install our system. The demo reactor will be located at one of the wastewater treatment facilities close to the metro area. A stable operation will be evaluated for a period of 24 months under more realistic hydraulic and temperature conditions. The reactor will be optimized under these conditions and the performance will be evaluated. Once the reactor achieves stable performance, the bacterial communities will be determined and compared with those of the laboratory experiments. In addition, the capacity of the system for pathogen inactivation will be determined by examining the concentration of pathogenic bacteria in the effluent of the reactor.

| Outcomes | Completion Date |
|---|---|
| *1. The onsite installation and operation of the gas-lift anaerobic membrane bioreactor.* | *03-30-2019* |
| *2. The operation and optimization of the onsite reactor.* | *02-28-2020* |
| *3. The identification of the bacterial communities present in the reactor.* | *03-30-2020* |
| *4. The determination of the pathogenic inactivation capabilities.* | *04-30-2020* |

**Activity 3:** *Techno-economical analysis and Life Cycle Assessment* **Budget: $35,000**
A technical and economical evaluation will be carried out in order to determine the feasibility of the proposed technology. The cost of installing and operating the proposed technology will be determined in terms of cost for a house owner. The results will be compared with traditional septic systems. In addition, the environmental benefits of the proposed technology will be determined by a Life Cycle Assessment in order to assess the environmental impact of our technology.

| Outcomes | Completion Date |
|---|---|
| *1. Technical and economical analysis.* | *05-29-2020* |
| *2. Life Cycle Assessment of the proposed technology.* | *06-30-2020* |

## III. PROJECT STRATEGY

### A. Project Team/Partners

Dr. Carlos Zamalloa, researcher at the Department of Bioproducts and Biosystems Engineering will lead and manage the research activities for this project. Carlos worked on an earlier LCCMR project M.L. 2014, Chp. 226, Sec. 2, Subd. 08g, "Next Generation Large-Scale Septic Tank Systems" for nutrient and energy capture. One graduate student will work on designing, building, operating and analyzing the performance of the reactors throughout this project.

### B. Project Impact and Long-Term Strategy

This project will encourage the implementation of emerging technologies for the treatment of rural wastewater. In addition, the knowledge acquired will fulfill the knowledge gap regarding the implementation of anaerobic membrane technologies for rural wastewater treatment. **In particular, the proposed technology in this project will allow a better and a more stable treatment of domestic sewage with a lower sludge production as well as potential energy generation leaving a positive impact on rural communities and the environment in Minnesota.** The implementation of such technologies will improve the quality of the water entering water bodies such as lakes and rivers and as such protecting human health and precious natural resources.

### C. Timeline Requirements

This project is planned to be executed within two years.

# 2018 Detailed Project Budget

**Project Title: Rural wastewater treatment: water reuse and energy production**

**IV. TOTAL ENRTF REQUEST BUDGET** *2* **years**

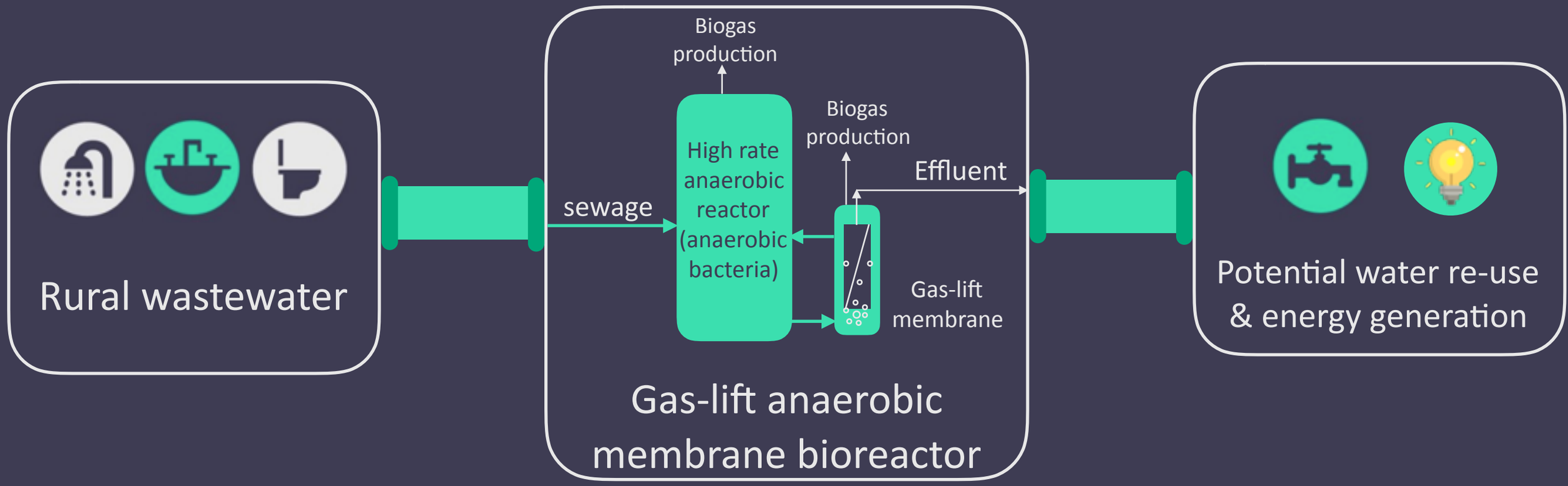
| BUDGET ITEM | AMOUNT |
|---|---|
| **Personnel:** | |
| Carlos Zamalloa, PI, Researcher (68% Salary, 32% Benefits), 100% FTE each year for year 1-2 | $ 136,000 |
| Bo Hu, Associate Professor (68% Salary, 32% Benefits), 8.3% FTE each year for year 1-2 | $ 28,000 |
| Graduate student, Research assistant, 50% FTE each year for year 1-2 | $ 90,000 |
| **Professional/Technical/Service Contracts:** | |
| **Equipment/Tools/Supplies:** | |
| Supplies for the lab experiments including chemicals, reagents and supplies for water quality analysis; equipment consumables such as ion chromatography columns; lab consumables such as acids, standards, vials and gloves. Repair and maintenance of analytical equipments. DNA extraction kits, DNA purification kits and qPCR sequencing. | $ 17,000 |
| Construction of gas-lift anaerobic bioreactors (lab-scale and demonstration reactors). Materials needed for the construction of the reactors such as commercially available membranes, glass and PVC high rate gas tight vessels, biogas counters, pumps, timers and controllers, sensors such as pH, temperature and pressure. Shipping of granular anaerobic sludge from wastewater treatment plant. | $ 17,000 |
| **Acquisition (Fee Title or Permanent Easements): N/A** | $ - |
| **Travel:** | |
| In-state travel (Mileage, lodging, and meals) for wastewater sample collection. Onsite set-up and operation. | $ 2,000 |
| **Additional Budget Items:** | |
| Professional service for water sample analysis at other UMN labs such as the characterization facility for membrane characterization (Scanning Electron Microscopy, SEM). | $ 4,000 |
| Publication costs for two papers | $ 3,000 |
| **TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =** | **$ 297,000** |

**V. OTHER FUNDS**

| SOURCE OF FUNDS | AMOUNT | Status |
|---|---|---|
| **Other Non-State $ To Be Applied To Project During Project Period:** | $ - | |
| **Other State $ To Be Applied To Project During Project Period:** | $ - | |
| **In-kind Services To Be Applied To Project During Project Period (Unrecovered F&A)** | $ 156,500 | *UM F&A* |
| **Past and Current ENRTF Appropriation** | $ - | |
| M.L. 2014, Chp. 226, Sec. 2, Subd. 08g, "Next Generation Large-Scale Septic Tank Systems" | $ 218,000 | ends in 6/30/2017 |
| **Other Funding History:** | $ - | |

# Rural wastewater treatment: water reuse and energy production

**Gas-lift anaerobic membrane technology will be used to develop a new and more sustainable rural domestic primary sewage treatment aiming to replace septic systems**




**Advantages:**

- Lower energy consumption
- Higher fluxes
- Higher effluent quality
- Energy generation

**Project Manager Qualifications**

The research team will include Dr. Carlos Zamalloa and Dr. Bo Hu from the Department of Bioproducts and Biosystems Engineering.

Dr. Zamalloa is a Researcher at the Department of Bioproducts and Biosystems Engineering of UMN. He works on sustainable biological wastewater treatments for resource recovery, in particular water, nutrients and biogas generation for energy generation. He has expertise in multiple areas including: Anaerobic Digestion (wastewater, sludge, solid waste and animal manure), Enhanced Biogas Generation (co-digestion, bio-electrochemical systems), Biological Wastewater Treatment, Membrane Bio-Reactors (MBR) and Water Reuse Applications and Technology

With regard to technical expertise, Dr. Bo Hu is an Assistant Professor at the Department of Bioproducts and Biosystems Engineering of UMN. He is also a joint faculty member of Biotechnology Institute of UMN. With over 10 years of active research experience specifically in biomass utilization, fermentative conversion, and molecular biology, he has led projects on microbial oil production from waste materials via mixotrophic microalgae and oleaginous fungal fermentation, and projects to develop the modified anaerobic digestion system for biohydrogen production and its microbial community change by using 16s rDNA based microbial analysis. Hu's team at UMN has set up several standard procedures such as 16s rDNA fingerprint screening for microbial species in the wastewater treatment facilities, ITS sequences to identify oleaginous fungal species; and several conversion platforms such as pelletized fungal fermentation, solid and hemi- SolidSF to accumulate oil from lignocellulosic materials. His research ideas have been funded by many programs, especially local funding agencies such as MN Pork Board, IOWA Pork Board, MN Rapid Agricultural Response Program, etc. to tackle regional issues.

Dr. Hu's lab is located at BAE 320B, adjacent to Dr. Hu's office. The lab space is around 1000 sqft and it is equipped with two laminar flow hoods and one clean bench. The lab has all the necessary equipment and facilities for this project, including a refrigerated shaker, two open air shakers, one incubation shaker, two incubators, one fermentation bioreactor, GC-FID-TCD, PCR thermal cycler, several electrophoresis, centrifuge, and ovens. The research group can also utilize facilities and equipment at the Biotechnology Resource Center (BRC), on a pay-per-sample base. BRC is a 4,000 square-foot laboratory/pilot plant facility with state-of-the-art equipment for research and development in fermentation, animal cell culture technology, molecular biology, protein expression, and separation of a wide range of biological molecules.

**Organization Description**

As the core department of UMN to tackle Agricultural engineering and environmental engineering issues, Bioproducts and Biosystems Engineering Department has very dynamic research activities and numerous excellent scientific researchers have received grant supports from LCCMR program. The collaborative partner Sara Heger works with the Onsite Sewage Treatment Program at the Water Resource Center of UMN. The program seeks to protect public health and the environment by improving wastewater treatment through research-based education and outreach for homeowners, small communities, professionals and policy-makers. UMN Sponsored Projects Administration (SPA) will be the entity authorized by the Board of Regents to manage the project agreements with LCCMR program.