Environment and Natural Resources Trust Fund
2014 Request for Proposals (RFP)

Project Title: **ENRTF ID: 121-E**

Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources

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

Total Project Budget: $ 2,041,626

Proposed Project Time Period for the Funding Requested: 3 Years, July 2014 - June 2017

Summary:

To demonstrate innovative technologies to utilize and treat wastewater streams; convert scum, sludge, and centrate to bio-fuels; improving water quality, reducing GHG emission, producing renewable energy, lowering wastewater treatment costs.

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

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

PROJECT TITLE: Demonstrating innovative technologies to fully utilize wastewater resources

I. PROJECT STATEMENT

Minnesota municipal wastewater treatment plants (MWTP) generate large amounts of oily scum, concentrated liquid (also called "centrate"), and sludge each year. For example, each year the 7 Metropolitan Council Environment Services (MCES) MWTPs treat more than 100,000 million gallons of wastewater and at the same time generate 1,000 tons of scum, 500 million gallons of centrate, and 850 million kg of dry sludge. These waste streams are either used as landfill (scum) and direct burning (sludge), or subjected to additional treatment (centrate). New technologies, developed by UMN researchers led by Dr. Ruan through several projects funded by federal and state grants, especially two ENRTF grants, can help capture the values from and lower the treatment costs for these waste streams. The **goal** of the project is to demonstrate the feasibility and effectiveness of implementing innovative technologies in Minnesota municipal wastewater treatment plants. The significant **outcomes** of the technologies are expected to include: (1) producing significant amounts of renewable energy for internal use or distributed to the market. Over 60 million gallons of biofuels and similar quantity of other biochemicals could be produced from the waste streams in MCES' facilities alone; (2) generating considerable revenues. Estimated annual revenue of $200 million could be generated from the fuels and other chemicals derived from scum, centrate, and sludge in these facilities; (3) improving wastewater treatment efficiency and cost effectiveness. The waste streams are effectively treated while they are converted to renewable energy; utilization of scum results in hundreds of thousands of dollars savings in landfill cost; algae are more effective than current processes in removing low level phosphorus; and (4) reducing environment pollutants. Landfill and fossil fuel and coal use will be significantly reduced; algae will sequester a large amount of carbons; CO_2 emission from sludge burning will be reduced.

Three activities, each with focus on one waste stream, are planned for the project. While the preparatory R&D and system development activities will be conducted at UMN, MCES Metro Plant in St. Paul, and FreightMaster/Minnesga Inc in Eagan, the final demonstration will be conducted in MCES Metro Plant. In the second half of the third year of the project, at least five demonstrations will be made to stakeholders including state agencies, private investors, academic researchers, and the public. Any intellectual properties and related revenues as a result of the program will be shared between UMN and LCCMR. The technologies, if demonstrated successfully, may be implemented to many MWTPs in the State of Minnesota and beyond.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: *Develop and demonstrate scum to biodiesel process and system* **Budget: $900,000**

Scum is the floatable materials skimmed from the surface of primary and secondary settling tank of the wastewater treatment system. Our research indicates that about 60% of the dry matter can be extracted and converted to biodiesel. Key technical steps to be further developed and optimized for the demonstrate include recovery of oil from scum, conversion of recovered oil to biodiesel, and upgrading biodiesel to meet industrial standards. An innovative biodiesel facility with capability to utilize low grade oils such as that from scum will be designed and constructed. Mass and energy balance data will be collected during testing operations, and used to provide evaluation of the technology through techno-economic analysis (TEA) and life cycle assessment (LCA). The system, together with the TEA and LCA results, will be demonstrated to the stakeholders.

Outcome	Completion Date
1. Develop and optimize oil recovery, conversion, and upgrading processes; Streamline processes and design the complete system	6/30/2015
2. Fabricate and install the system at demonstration site	12/31/2016
3. Test the system and collect mass and energy balance data; conduct TEA and LCA	03/31/2017
4. Demonstrate the systems to stakeholders	06/30/2017

Activity 2: *Develop and demonstrate centrate to algae fuel system* **Budget: $600,000**

Centrate is proved to be a highly adequate medium for algae growth with very high removal rates for chemical oxygen demand (COD), nitrogen (N), and phosphorus (P). Key technical steps to be further developed

include addition of crude glycerol from biodiesel process to centrate to provide additional carbon source for further removal of N and P. The multi-layer hybrid photobioreactors technology developed through previous ENRTF funded project will be used in the algae based wastewater treatment and biomass harvest facility for demonstration. A pilot scale system will be designed, constructed, and installed in the demonstration site.

Outcome	Completion Date
1. Develop and optimize algae growth and nutrient removal involving crude glycerol; design the complete processes.	6/30/2015
2. Design and construct a greenhouse based algae based wastewater treatment facility	12/31/2016
3. Test the facility and collect mass and energy balance data; conduct TEA and LCA	03/31/2017
4. Demonstrate the systems to stakeholders	06/30/2017

Activity 3: *Develop and demonstrate sludge to bio-fuels system* **Budget: $541,626**

Sludge is currently burned to produce heat for power generation. A fast microwave assisted pyrolysis (fMAP) process developed by UMN researchers through another ENRTF funded project can be used to convert sludge to high energy density liquid fuels. Key technical steps to be further developed and optimized include dewatering efficiency, implementing microwave absorbents to improve heating rate in the system, improving fuel yield, and upgrading fuels to meet industrial standards. A pilot scale continuous dewatering and fMAP system will be designed, constructed, and installed in the demonstration site.

Outcome	Completion Date
1. Develop cost effective dewatering process; design microwave absorbent device; optimize catalytic bio-oil upgrading process	6/30/2015
2. Design and construct a complete facility for dewatering and conversion of sludge to bio-oil and syngas; the facility is expected to be fully or partially self-powered.	12/31/2016
3. Test the facility and collect mass and energy balance data; conduct TEA and LCA	03/31/2017
4. Demonstrate the systems to stakeholders	06/30/2017

III. PROJECT STRATEGY

A. Project Team/Partners

UMN: Dr. Roger Ruan - PI & project director, will be responsible for overall project planning and budget control, development, design and evaluation of the demonstration facilities; Dr. Paul Chen - co-PI, will be responsible for experiment design and coordination, monitoring and documentation of project progress and results, and publicizing the project; Dr. Min Min and Mr. Richard Griffith will assist Drs. Ruan and Chen with process development and facility design and construction, and conducting the economic and environmental life-cycle analysis. **MCES** Metro Plant: Mr. Larry Rogacki, Director of Plant Services, will provide necessary support to the project and is committed to meeting with the project team, developing a work plan and system details, and providing raw material samples, space at the plant for conducting studies, and technical feedback. A support letter from Metro Plant is enclosed. They will not receive fund from LCCMR. **FreightMaster/Minnesga Inc:** Mr. John Snyder will provide space necessary for equipment development, help with equipment and fuel testing as described in their support letter. They will not receive fund from LCCMR.

B. Timeline Requirements

This is a three-year project. The first two and half years are required to develop and construct the systems. In the third year, the systems will be tested and demonstrated. The results from the project will be important to further R & D and eventual commercialization.

C. Long-Term Strategy and Future Funding Needs

The proposed project, built on our existing technologies, does not need additional investment other than the requested ENRTF support to complete. However, further development and demonstration leading to eventual technology transfer and commercialization will be our long-term goal and will require additional funding. Next level commercial scale-up pilot facilities demonstrations may be necessary with federal, state, and private funding before the technologies can be commercialized.

2014 Detailed Project Budget

Project Title: *Demonstrating innovative technologies to fully utilize wastewater resources*

IV. TOTAL ENRTF REQUEST BUDGET *3* years

BUDGET ITEM	AMOUNT
Personnel:	$ -
Roger Ruan, PI/PD, 8.3%, 3 years, including 33.6% benefits, leading and managing project, overlooking R&D, leading demonstration, supervising postdocs and RA	$39,971
Paul Chen, co-PI, 25%, 3yrs, including 33.6% benefits, project coordination, conducting R&D, project evaluation, progress report	$80,500
2 research associate 100%, 3yrs, including 20.75% benefits, conducting R&D, operations, demonstration, data analysis	$ 379,909
2 Postdocs, 100%, 3yrs, including 20.75% benefits, conducting R&D, operations, demonstration, data analysis	$ 298,581
2 Graduate Research Assistants, 50%, 3yrs, including 15.7% benefits plus tuitions, conducting R&D, operationg, demonstration	$ 246,947
Equipment/Tools/Supplies:	$ -
Biofeul testing instruments for testing fuel flash point, cloud point, total glycerol, moisture content	$ 40,000
Lab scale distiller for biodiesel purification	$ 30,000
Glassware for lab scale biodiesel conversion during process development and optimization	$ 10,000
Pilot scale biodiesel conversion system including oil extraction device, reaction tank, storage tanks, separation tanks, fractional rectifier, pumps, heaters, heat exchangers, control	$ 300,000
algae cultivation and harvesting system including multi-layer photobioreactors, greenhouse, circulation equipment, harvest equipment, dewatering equipment	$ 200,000
Fast microwave assisted pyrolysis system including auto-feeder, magnitrons, reaction chamber, microwave absorbent bed, condensor, syngas scraper, gas turbine power generator	$ 250,000
Laboratory supplies including chemicals, analytical supplies, microwave absorbents, catalysts, glassware, containers, printing	$ 150,000
Travel:	$ -
for researchers to travel between campus and demonstration site over the 3yrs project period	$ 15,718
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$2,041,626

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to:		
MCES	$ 52,036	*Pending*
In-kind Services During Project Period:		
Unpaid F&A on ENRTF request based on 52% MTDC rate	$ 579,323	*Pending*
Remaining $ from Current ENRTF Appropriation (if applicable):	$ -	
LCCMR. Wastewater algae pilot project (no cost extension till 9/30/13)	$ 50,000	unspent
Funding History:	$ -	
UMN IREE and MCES. Mass culture of algae from wastewater	$ 750,000	completed
USDA/DOE. Development of Scalable Biorefining Processes for Distributed Biomass Conversion.	$ 1,200,000	completed
US DOT and Sun Grant Initiative. Develop sustainable renewable energy systems for practical	$ 1,100,000	completed
LCCMR. Mobil biomass pyrolysis system development and demonstration	$ 500,000	completed
UMN IREE. Catalytic reforming of liquids and gases from thermochemical and biological conversion of biomass.	$ 250,000	completed

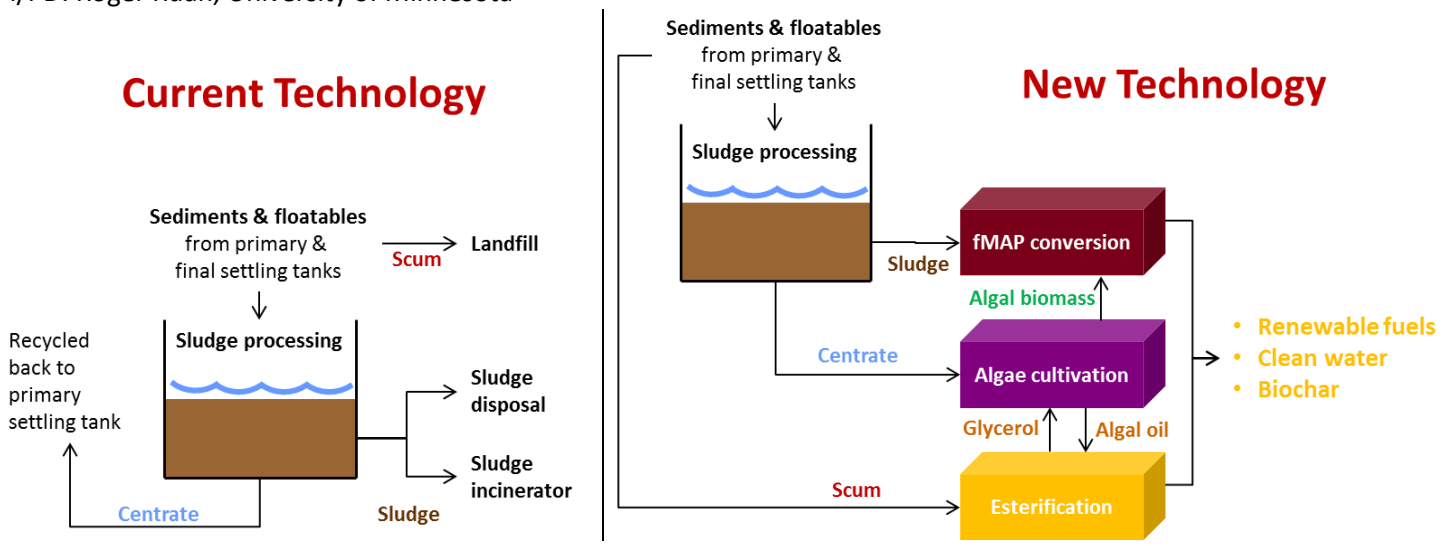

Figure 1. A comparison of waste stream pathways between the current and proposed new technologies

Figure 2. Pilot scale animal wastewater algae production facility in Rosemount, developed through previous LCCMR and other projects.

Figure 3. Pilot scale mobile MAP system developed through previous LCCMR and other projects; with incorporation of microwave absorbents, it becomes fMAP, a superior fast thermochemical conversion process.

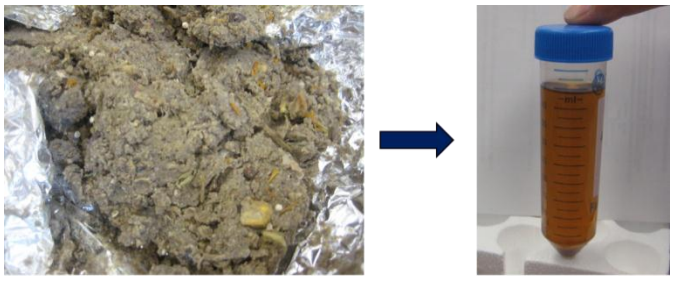

Figure 4. Converting scum to biodiesel

Project Manager Qualifications and Organization Description

Dr. Roger Ruan, Professor and Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, co-leader of Bioenegy and Bioproducts Cluster of the Initiative of Renewable Energy and Environment (IREE), University of Minnesota, is the project manager of the proposed project. Dr. Ruan's research focuses on renewable energy and the environment as well as food safety and quality. Dr. Ruan has published over 200 papers in refereed journals, books, and book chapters, and over 300 additional meeting papers and other reports, and holds 12 US patents. He has supervised more than 40 graduate students, 60 post-doctors, research fellows, and other engineers and scientists, and 9 of his students hold university faculty positions. He has received over 140 projects totaling over $20 millions in various funding for research. He is an editor-in-chief of the *International Journal of Agricultural and Biological Engineering* and editorial board member of *Journal of Food Process Engineering*, and Associate Editor of *Transactions of ASABE*, *Engineering Applications in Agriculture, and Transactions of CSAE*. Dr. Ruan has given over 180 invited symposium presentations, company seminars, and short courses, and has been a consultant for many local, national, and international companies and agencies in renewable energy and products as well as food and value-added processing areas. Dr. Ruan has also given frequent interviews on related topics to various news media.

Dr. Ruan has very active ongoing research programs on renewable energy. Algae production and processing is a major focus of his current research. They have screened more than 100 microalgae species and strains collected from commercial algae banks and local waters. Several species and strains have been identified as candidates for mass culture on concentrated wastewater. They have developed and tested many algae culture systems. One system with great potential for cost effective production of algae is being closely evaluated and a patent disclosure has been filed. Two small pilot systems have been built and are being tested in a green house on St. Paul campus and in one of the MCES wastewater plants in St. Paul. One large production facility is located in UMN Rosemount Research and Outreach Center. Both of the Center for Biorefining and MCES have the expertise and experience to develop, construct, and operate pilot scale microalgae production systems and wastewater treatment.

The Center for Biorefining is a University of Minnesota research center and help coordinate the University efforts and resources to conduct exploratory fundamental and applied research; provide education on bioenergy, biochemicals and biomaterials; stimulate collaboration among the University researchers, other public sector investigators, and private investigators involved in biobased production technology development; promote technology transfer to industries; and foster economic development in rural areas. The Center's research programs are founded by DOE, USDA, DOT, DOD, LCCMR, IREE, Xcel Energy, and other federal and state agencies, NGOs, and private companies. The Center is equipped with state of the arts analytical instruments, and processing facilities ranging from bench to pilot scale.