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

Project Title: **ENRTF ID: 176-E**

Produce Marketable Liquid Fuels from Plastic Wastes

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

Sub-Category:

Total Project Budget: $ 383,000

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

Summary:

Evaluate and develop conversion technology for production of high quality and marketable liquid fuels from plastic wastes and hence reduce solid pollutants and protect the environment.

Name: Paul Chen

Sponsoring Organization: U of MN

Job Title: Professor

Department: College of Food, Agricultural and Natural Resource Sciences

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Location:

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

Illustrates the negative impacts of plastic wastes on environment and ecology, preliminary data and research interest of the proposed solutions, and potential outcome and benefits of the project.

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

PROJECT TITLE: Produce marketable liquid fuels from plastic wastes

I. PROJECT STATEMENT

Solid wastes, particularly non-biodegradable plastic wastes, are an immense and growing environmental problem. Of the over 100 million annual tons of plastic waste, less than 10% is recycled. Much of it makes its way into rivers and disposes into the ocean, landfills, or is incinerated. By converting plastic wastes to liquid fuels, wastes can be intercepted and re-used, greatly reducing potential environmental and ecological impacts. The total conversion ***economic opportunity is over $29 billion in the US alone***, spurring the phrase "landfills are the future goldmine". This project is designed to evaluate and develop conversion technology for production of high quality and ***marketable liquid fuels from municipal solid wastes*** and hence ***reduce solid wastes and protect the environment***. The project addresses *Priority E: Air Quality, Climate Change, and Renewable Energy*.

To further illustration the significance of the problems with plastic waste, consider these facts:

- Recent studies show ***microplastics***, which are tiny plastic fragments that wear off of synthetic clothing, fall off decomposing plastic bags and bottles, and are manufactured into some products, ***pollute lakes and rivers***, and ***endanger wild lives and biodiversity***.
- Plastics contain ***toxins*** that are linked to cancer, birth defects, immune-system problems, and childhood developmental issues.
- In addition to contaminating ocean waters, ***94 percent of tap-water samples in the United States contained plastic fibers***. ***Plastics can also disturb forest and clog waterways***.
- Plastic wastes are a significant economic burden to waste treatment infrastructure.

Conversion of waste plastic to high-quality fuels and chemicals still has many ***technical, economic, and environmental challenges***. Briefly, current conversion processes have low usable fuel yields, low fuel quality, and are economically infeasible. These issues significantly impact the viability of converting waste plastics into usable and marketable products and must be addressed before the technology can be commercialized.

LCCMR provided support to our pyrolysis project in 2007 funding process (M.L. 2007) to develop microwave assisted pyrolysis (MAP) of biomass. LCCMR subsequently funded a number of projects that involved development of microwave assisted pyrolysis of biomass. As a result, the technology has evolved from moderate heating rate processing to fast microwave assisted pyrolysis (fMAP) that can be used to convert biomass to liquid and gaseous fuels and biochar. ***Our preliminary research indicated that plastics are an excellent feedstock for liquid fuel production*** because they have high hydrocarbon content and no or little oxygen content. We also found a relatively large fraction of wax among the products from pyrolysis of plastics without adequate catalysts. ***The liquid product contains hydrocarbons found in gasoline and diese***l. We are ready to tweak the fMAP for plastics and evaluate its environmental and economic impacts.

The ***overall goal*** of our research program is to develop and commercialize plastic-to-fuel (PTF) technology that will prevent plastic wastes from polluting Minnesota lands and waters and at the same time produce marketable products. The efforts planned for this project are to go beyond proof of concept and develop process specifically for plastic wastes as the feedstock. The ***specific objectives*** of the project include:

(1) Process development: study of effects of processing temperature, heating rate, catalysts, methods of feeding plastics, presence of biomass on product yield and quality; optimization of the process.
(2) Impact assessment: preliminary input-output analysis to provide assessment of economic potential and environmental and ecological benefits.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: *Develop and investigate processes for converting plastic wastes to high quality liquid fuels*

Plastic wastes may come in different compositions. Some are pure plastics containing a single type or mixture of different plastic materials from manufacturing sources; some contain non-plastic materials such as those from municipal solid wastes. We will first test different feedstocks using standard process with our lab

experimental apparatus. The results from the initial tests will guide our further development and investigation of processes designed for specific feedstock compositions. The key processing parameters and conditions to be investigated and adjusted are heating rate, temperature, feeding rate, and catalysts. The yields of liquid, gas, and char fractions will be measured; the chemical composition and energetic properties of the liquid will be determined to evaluate the fuel quality. These planned activities are expected to generate information that will help us understand the relationships between processing variables and product yield and quality, laying the foundation for further R&D to move the technology to commercial sectors.

ENRTF BUDGET: $200,000

Outcome	Completion Date
Collection and characterization of plastic wastes	*09/30/2020*
Initial test of microwave assisted pyrolysis of plastic wastes	*12/31/2020*
Process development and investigation	*12/31/2022*
Evaluation of the process and product yield and quality	*12/31/2022*

Activity 2: *Evaluate the potential economic, environmental and ecological impacts of the proposed technology*

For this small project, we plan to conduct preliminary studies to provide big pictures of the potential economic, environmental and ecological impacts of the plastic-to-fuel technology. Additional data on mass and energy balance will be collected. Greenhouse gas emission during the process will be monitored. An input-output model will be used for economic analysis. The energy consumption, greenhouse gas emission, and waste reduction will be considered in the assessment of environmental and ecological impacts of the technology.

ENRTF BUDGET: $183,000

Outcome	Completion Date
Collection of mass and energy balance data	*12/31/2022*
Monitoring of greenhouse gas emission	*12/31/2022*
Estimate of potential reduction in plastic waste and production of valuable products	*06/30/2023*
Preliminary assessment of economic, environmental, and ecological impacts	*06/30/2023*

III. PROJECT PARTNERS:

A. Project team:

Paul Chen (BBE, UMN), Roger Ruan (BBE, UMN)

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
John Snyder	President	Minnesga	Help with system development and evaluation

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

New scientific knowledge and experience on microwave assisted pyrolysis of plastic wastes will be acquired through research. Processes for specific plastic wastes will be developed. The potential economic, environmental and ecological impacts will be presented to the stakeholders to raise their awareness and attract their support. We will seek industry partners and private, state, and federal funding to further develop and eventually commercialize the technology.

V. TIME LINE REQUIREMENTS:

This project is planned for 3 years beginning July 1, 2020 and ending June 30, 2023. Most of the first 30 months will be focused on the development and understanding of the processes, and much of the last 6 months will be focused on assessment of the impacts of the technology.

Attachment A: Project Budget Spreadsheet
Environment and Natural Resources Trust Fund
M.L. 2020 Budget Spreadsheet
Legal Citation:
Project Manager: Ling (Paul) Chen
Project Title: Produce marketable liquid fuels from plastic wastes
Organization: University of Minnesota
Project Budget: $383,000
Project Length and Completion Date: 3 Years - June 30, 2023
Today's Date: 4/11/19

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ 278,000	$ -	$ 278,000
Paul Chen, PI/PD, .24 FTE, 3 years, $96,000, 73.5% salary, 26.5% fringe; leading and managing lab and field testing project, leading demonstration, supervising graduate student.			
Roger Ruan, co-PI, 0.04 FTE, $34,000, 73.5% salary; 26.5% fringe, coordinating lab testing and analysis, supervising graduate student.			
TBA, graduate student, 0.5 FTE, $148,000, 65% salary, 35% fringe			
Professional/Technical/Service Contracts			
	$ -	$ -	$ -
Equipment/Tools/Supplies			
Lab supplies, instrument and equipment consumables, minor equipments for settting up lab and field experimental and testing and demonstration systems and equipment repairs and calibration	$ 90,000	$ -	$ 90,000
Capital Expenditures Over $5,000			
	$ -	$ -	$ -
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
Travel to collect samples in fields and demonstration site over the 3 yr project period	$ 5,000	$ -	$ 5,000
Other			
Outside analysis service for sample analysis and equipment maintenance	$ 10,000	$ -	$ 10,000
COLUMN TOTAL	$ 383,000	$ -	$ 383,000

SOURCE AND USE OF OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind: Unrecovered F&A		$ 181,000	$ -	$ 181,000

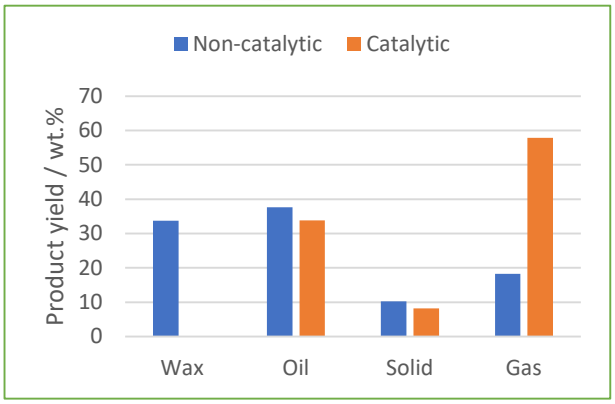
Other ENRTF APPROPRIATIONS AWARDED IN THE LAST SIX YEARS	Amount legally obligated but not yet spent	Budget	Spent	Balance
M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$ -	$ 1,000,000	$ 1,000,000	$ -

90%

Impacts

- Pollute land, rivers, and lakes
- Pollute drinking water
- Linked to cancer, birth defects, immune-system problems, and childhood developmental issues
- Endanger wild lives and biodiversity
- Disturb forest and clog waterways
- A significant economic burden to waste treatment infrastructure

10% Recycle



Preliminary data show that without catalyst, a large fraction of wax (low value) was produced. The use of catalyst eliminated wax altogether; however, a large fraction of syngas was produced. The goal is to develop a process that produces high yield and high quality liquid transportation fuel (oil).

Small pilot scale microwave assisted pyrolysis system

Key processing parameters

- Plastic types
- Heating rate
- Temperature
- Catalysts
- Feeding rate

Outcome of the Project

- Processes will be developed and investigated for conversion of plastic wastes to transportation fuels
- Potential economic, environmental and ecological impacts of the proposed strategy will be evaluated
- Stakeholders will be presented with the research findings and recommendations for further actions
- The research findings will be used for seeking industrial partnerships and external funds for further R & D efforts

Project Manager Qualifications and Organization Description

Dr. Paul Chen, Associate Research Professor and Program Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, University of Minnesota, is the Project Manager of the proposed project. He has managed many projects aimed to develop technologies for production of renewable energy and materials and protection of the environment. He is a co-investigator of 5 LCCMR funded projects in the past 10 years or so, ***which resulted in the issuance of a US patent (scum to biodiesel) and licensing of a technology (microwave assisted conversion of biomass)***. He has also been involved in many renewable energy and environment related projects funded by federal agencies such as DOE, USDA, DOT, DOD, Sun Grants, etc., and private organizations. He is an inventor of 15 US patents. He is well published with more than 180 papers on peer-reviewed journals.

Relevant to the proposed project, Paul has been conducting research and development in the conversion of biomass and municipal solid wastes to valuable energy and materials. One of the core technologies he helped develop is microwave assisted pyrolysis and gasification. Over the last 10 years or so, Paul and his co-workers have improved the process from moderate processes to fast processes. As a result, the product yields and quality are significantly higher than before. They have also designed and fabricated two large testing and demonstration systems.

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. In particular, they have the capability to develop microwave assisted conversion systems and processes for different feedstocks and applications.