Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-350

Proposal Title: Plastic-Wastes to Fuels and Chemicals through Microwave-Assisted Pyrolysis

Project Manager Information

Name: Roger Ruan

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

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Project Basic Information

Project Summary: Convert plastic wastes to liquid fuels and chemicals through microwave-assisted pyrolysis (MAP) technology and thus provide an affordable tool for solid waste management and valorization

Funds Requested: $914,000

Proposed Project Completion: 2024-06-30

LCCMR Funding Category: Water Resources (B)

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?

During the Project and In the Future

Narrative

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

Plastic polymers are ubiquitous and integral in our society; unfortunately, plastic wastes are turning into an immense and growing environmental problem. Of the over 100 million annual tons of plastic waste, less than 10% is recycled. Much of the non-recycled plastics make its way into rivers, lakes, oceans, landfills, or is incinerated. Recent studies show microplastics, which are tiny plastic fragments that wear off of plastic containing products, pollute lakes and rivers, and endanger wild lives and biodiversity. Some plastics even 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. On the other hand, plastic wastes could be a valuable resource if handled properly. By converting plastic wastes to liquid fuels, chemicals, and material, 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”.

What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.

This project is designed to evaluate and develop a microwave-assisted pyrolysis (MAP) based conversion technology for production of high quality and marketable liquid fuels from plastic wastes and hence reduce solid wastes and protect the environment. The project addresses Priority B.2.II: Water Resources: Preventing or reducing levels of contaminants in ground and surface waters.

Pyrolysis is a promising technology to achieve efficient conversion of waste plastic to valuable products, with very attractive results reported in literature. Yet, successful attempts to commercialize this technology remain unseen so far as most reported industrial attempts struggle with yield and quality issues of the products. Several challenges, including reactor design, operating conditions optimization, and catalyst application, have to be overcome in order to scale up the technology and make the process economically viable.

Our MAP technology was initially developed under funding support from LCCMR in 2007 for converting biomass to biofuels. Subsequent support from LCCMR and several other agencies has contributed to its evolution into continuous fast microwave assisted pyrolysis (cfMAP) with continuous operation and enhanced heating rate that can more efficiently convert biomass to liquid and gaseous fuels and biochar. Our preliminary research indicated that cfMAP system can effectively convert plastic wastes into liquid fuels featuring high hydrocarbon content and negligible oxygen content. We also have identified several potential catalyst candidates, including layered clay catalysts and Ni/Al2O3 catalyst, that could promote the production of liquid fuels and other higher-value products. We are ready to tweak the cfMAP system for plastics and evaluate its environmental and economic impacts.

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?

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 specific outcomes of the project will include:

(1) Process development and optimization: experimental results will be generated by studying the effects of various process conditions including temperature, heating rate, catalysts, methods of feeding plastics, and presence of biomass and/or contamination, on product yield and quality;

(2) Impact assessment: experimental data will be collected to conduct preliminary input-output analysis to provide assessment of economic potential and environmental and ecological benefits;

Activities and Milestones

Activity 1: Evaluate the potential economic, environmental and ecological impacts of the proposed technology

Activity Budget: $114,000

Activity Description:
For this 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.

Activity Milestones:

Description	Completion Date
Collection of mass and energy balance data	2023-12-31
Estimate of potential reduction in plastic waste and production of valuable products	2024-06-30
Preliminary assessment of economic, environmental, and ecological impacts	2024-06-30

Activity 2: Develop a MAP system and investigate processes for converting plastic wastes to high quality liquid fuels

Activity Budget: $500,000

Activity Description:
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 representative 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 are heating rate, temperature, and feeding rate. 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.

Activity Milestones:

Description	Completion Date
Collection and characterization of plastic wastes	2021-09-30
Initial test of microwave assisted pyrolysis of plastic wastes using a bench system	2021-12-31
Process development and investigation using a bench system	2022-12-31
Develop a small pilot scale MAP conversion system	2023-06-30
Evaluation of the process and product yield and quality	2023-12-31

Activity 3: Catalyst screening and optimization of catalyst application

Activity Budget: $300,000

Activity Description:

Catalysts play a vital role in the plastic-to-fuels, chemicals and materials process as they are essential in adjusting product distribution and/or selectively producing specific products. Most of the catalysts studied so far for plastic pyrolysis are zeolites, which are adapted from similar processes in petroleum refinery industry. The shortcomings of zeolites for plastic pyrolysis include their high costs and rapid deactivation. In this study, we will screen a range of potential catalyst candidates in lab-scale apparatus to evaluate their performance on plastic pyrolysis. Catalyst modifications will be applied if necessary in order to find cost-effective and high-performance catalysts specific to different feedstock or desired products. Catalyst application conditions including catalyst to feedstock ration, catalysis temperature, and catalyst reactor configuration, will be optimized for plastic pyrolysis. In addition, different options of catalyst regeneration will be tested and evaluated from the perspective of scale-up operations.

Activity Milestones:

Description	Completion Date
Screening and performance evaluation of potential catalyst candidates	2022-06-30
Optimization of catalyst application conditions	2022-12-31
Evaluating different designs of catalyst regeneration process	2022-12-31

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Paul Chen	University of Minnesota	co-PI	Yes
Yanling Cheng	University of Minnesota	co-PI	No

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 be funded?

New scientific knowledge and experience on microwave assisted pyrolysis of plastic wastes will be acquired through research. 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.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Demonstrating Innovative Technologies to Fully Utilize Wastewater Resources	M.L. 2014, Chp. 226, Sec. 2, Subd. 08c	$1,000,000
Development of Innovative Sensor Technologies for Water Monitoring	M.L. 2016, Chp. 186, Sec. 2, Subd. 04j	$509,000

Project Manager and Organization Qualifications

Project Manager Name: Roger Ruan

Job Title: Professor and Director

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Roger Ruan, Professor and Director, Center for Biorefining and Department of Bioproducts and Biosystems Engineering, University of Minnesota, Fellow of ASABE and Fellow of IFT, is the project manager of the proposed project. Dr. Ruan's research focuses on renewable energy technologies, solid and liquid waste treatment and utilization, and environmental engineering. Specifically, he has conducted research and published his findings in the areas of municipal, agricultural, and industrial wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation, and hydroponic cultivation, biomass and solid wastes (including plastics) gasification and pyrolysis, airborne pathogen disinfection, catalysis, non-thermal plasma, ammonia synthesis, etc. He is a top-cited author in the area of agricultural and biological sciences with an h-index of 63, i10-index of 255, and over 15,400 citations, and has received over 180 projects totaling over $45 million in various funding for research, including major funding from USDA, DOE, DOT, DOD, LCCMR, and industries. He was the project manager of several earlier LCCMR funded projects which resulted in the issuance of a US patent and licensing of a technology. Therefore he has the technical expertise and project management experience to ensure the execution of proposed projects.

Organization: U of MN - College of Food, Agriculture and Natural Resource Sciences

Organization Description:

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.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Roger Ruan		Principal Investigator			36.5%	0.12		$24,328
Post Doc		Researcher			25.4%	3		$193,799
Paul Chen		Co-Principal Investigator			36.5%	0.48		$64,621
Graduate Research Assistant		Research Assistant			45%	1.5		$150,933
Graduate Research Assistant		Research Assistant			45%	1.5		$150,933
							Sub Total	**$584,614**
Contracts and Services								
							Sub Total	-
Equipment, Tools, and Supplies								
	Tools and Supplies	Purchase of lab and miscellaneous supplies, including feedstock, catalysts, chemicals, consumable supplies for analytical instruments	For running experiments and operating conversion systems					$23,386
	Equipment	Components for fabrication of a small pilot system including reactor vessel, insulation materials, magnetrons, power supply and control, motors, mixer, feeder, valves, etc.	To fabricate a small pilot system for extensive testing, cost and emission analysis, and demonsration					$300,000
							Sub Total	**$323,386**
Capital Expenditures								
							Sub Total	-
Acquisitions and Stewardship								

							Sub Total	**-**
Travel In Minnesota								
							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Repairs and Maintenence	Repairs and Maintenance of analytical instruments					$6,000
							Sub Total	**$6,000**
							Grand Total	**$914,000**

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				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Attachments

Required Attachments

Visual Component

File: e6c86b6e-e28.pdf

Alternate Text for Visual Component

1) impacts of plastic wastes on the environment and ecosystems
2) our solution
3) key parameters to be studied
4) expected outcomes

Optional Attachments

Support Letter or Other

Title	File
UMN authorization letter	973ba0f9-3c4.pdf
UMN financial audit report	0482e250-23c.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

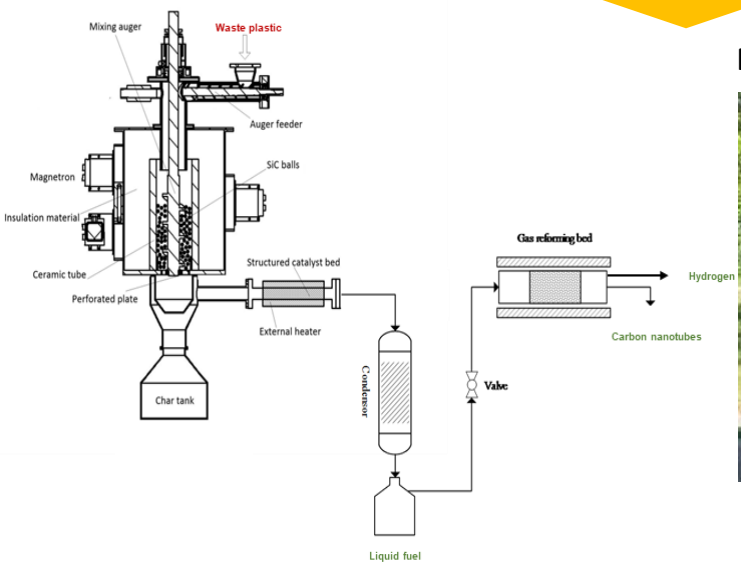
No

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

solution



Pilot scale microwave assisted pyrolysis system

Our preliminary research indicated that plastics can be effectively converted into high-yield liquid fuels and achieve co-production of hydrogen and carbon nanotube at the same time by using this continuous system. The liquid fuels can be easily separated and upgraded into gasoline and diesel. We also found that pillared clay and Ni/Al_2O_3 catalysts are feasible and promising for plastic pyrolysis vapor reforming into liquid fuels and hydrogen/carbon nanotube production, respectively.

Processing parameters

- Plastic types
- Heating rate
- Temperature
- Residence time
- Feeding rate

Outcome of the Project

- An advanced microwave pyrolysis technology will be developed for cost effectively converting plastic wastes to liquid fuels, hydrogen, and carbon nanotube
- 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