

**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

**Office Telephone:** (612) 625-1710

**Email:** ruanx001@umn.edu

## **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. Ineli gible** | **% Bene fits** | **# FTE** | **Class ified 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](https://lccmrprojectmgmt.leg.mn/media/map/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](https://lccmrprojectmgmt.leg.mn/media/attachments/973ba0f9-3c4.pdf) |
| UMN financial audit report | [0482e250-23c.pdf](https://lccmrprojectmgmt.leg.mn/media/attachments/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