



# Environment and Natural Resources Trust Fund

2023 Request for Proposal

## General Information

**Proposal ID:** 2023-150

**Proposal Title:** Production and Utilization of Fuels from Landfill Waste

## Project Manager Information

**Name:** Sayan Biswas

**Organization:** U of MN - College of Science and Engineering

**Office Telephone:** (612) 625-6012

**Email:** biswas@umn.edu

## Project Basic Information

**Project Summary:** This proposal aims to demonstrate a) production of low-carbon fuels from single-use plastics and organic wastes, and b) utilization of waste-derived fuels sustainably and efficiently to power engines.

**Funds Requested:** \$205,000

**Proposed Project Completion:** June 30, 2025

**LCCMR Funding Category:** Air Quality, Climate Change, and Renewable Energy (E)

## 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.**

The US produces over 380 million tons (MT) of plastic every year; 50% is for single-use purposes – utilized for a moment but stays on the planet for several hundred years, which threatens our climate, ecosystem, health, and food safety. Landfill wastes release methane - a greenhouse gas, create fire hazards, pollute groundwater and lakes by seeping hazardous materials. Technologies that can minimize landfill wastes sustainably, scalably, and profitably can be a game-changer for the environment and economy. Per Minnesota Pollution Control Agency, Minnesota produced nearly 3.5 MT of solid waste in 2020, of which only 18% was recycled, and the rest went into landfills. The energy content of the unused annual landfill of plastics and organic wastes is equivalent to 30% of yearly US gasoline consumption. The US consumes nearly 150 billion gallons of gasoline every year, equivalent to 100 MT of gasoline. In 2018, the amount of single-use plastics (40%) and organic wastes (60%) in landfills was 70 MT. Our catalytic waste-to-fuel conversion efficiency is 80% for plastics and 50% for organic wastes. Assuming waste fuels calorific value is 70% of gasoline leads to a staggering 30 MT of gasoline-equivalent - 30% of the US annual gasoline usage.

### **What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.**

We are proposing innovative technologies to a) produce waste fuels by recycling single-use plastics and organic wastes, b) utilize the fuels to fit into existing engine architecture, and c) optimize the combustion performance and emissions of these fuels. First, we will employ Catalytic Microwave-Assisted Pyrolysis – a pioneering technique to produce ‘designer’ low-carbon synthetic fuels from solid wastes, with a high waste-to-fuel conversion efficiency (80% for single-use plastics). Second, we will tailor the physical and chemical properties of the fuels to utilize in off-road engines such as farm tractors, excavators, bulldozers, portable generators, etc. Third, we will demonstrate a novel injector technology to spray the viscous waste fuels and a plasma igniter technology that outperforms conventional spark igniters to improve combustion performance. Finally, after testing a wide variety of waste-derived fuels, optimizing the production cost, fuel refinement steps, combustion performance and emissions – a fuel will be identified for next-phase large-scale production in collaboration with our local industry partners. The ultimate objective of our project is to enable the local Minnesota industry to find a cost-effective, low-carbon waste fuel that will power the agriculture and energy sector for decades to come.

### **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?**

Treating waste as a resource benefits our environment and economy. Recycling creates jobs – nearly 37,000 jobs in MN are directly or indirectly supported by the industry, adding nearly \$8.5 billion to Minnesota’s economy. Recycling generates profits – in 2015, Minnesota recycling programs collected approximately 2.5 MT of material worth \$690 million. Insufficient recycling is revenue lost – in 2018, Minnesota spent nearly \$200 million to dispose of 1.2 MT of recyclable material into landfills that could easily have been recycled for an additional estimated value of \$285 million. Recycling benefits the environment by conserving energy and reducing landfills.

## Activities and Milestones

### Activity 1: Synthesizing waste fuels with improved yield and quality

**Activity Budget:** \$50,000

**Activity Description:**

In this activity, our team will produce high-quality fuels from single-use plastics and organic solid wastes. In order to keep the cost low, the number of refinement steps must be limited. Two major tasks will be completed under Activity 1: (a) gain a clear understanding of the waste-to-fuel catalysis processes and find a balance between yield and quality, and (b) develop durable and robust catalysts with superior longevity and effectiveness. The key processing parameters and conditions to be investigated and optimized are pyrolysis/catalysis temperature, residence time, and catalysts. These planned activities are expected to generate information that will help us understand the relationships between processing variables and fuel quality and performance in engine testing.

We will collaborate with our long-standing industry partners, Resynergi company and Minnesga, to perform a cost-benefit analysis and identify the potential sectors to test the waste fuels. In the past, Resynergi company licensed our previous waste-to-fuel technology from the University of Minnesota deploying a 1-ton pilot commercial waste conversion plant to produce liquid hydrocarbon products. We will be partnering with Reysnergi or a regional company to synthesize waste fuels to test in off-road construction and agricultural engines such as backhoes and tractors.

**Activity Milestones:**

Description	Completion Date
Improve and optimize yield and quality of waste fuel production	December 31, 2023
Complete testing different catalyst for longevity and performance	March 31, 2024
Perform physical and chemical property evaluation of waste fuels	April 30, 2024
Activity 1 summary report	May 31, 2024

### Activity 2: Develop novel fuel injectors capable of handling high-viscosity waste fuels

**Activity Budget:** \$50,000

**Activity Description:**

In this activity, spray quality will be assessed for the highly viscous waste fuels synthesized in Activity 1. The density, viscosity, and fluid flow characteristics of waste fuels will be measured using rheometers in the Polymer Characterization Laboratory located in Chemical Engineering and Materials Science. A critical factor towards efficiency and clean combustion of waste fuels is determined by the fuel atomization and mixing, i.e., how fine mist the fuel injector can produce. Our novel counterflow atomizer uses high-pressure gases to aerate the viscous waste fuels to produce a fine mist. This would enable a uniform and clean burning of these waste fuels under any engine conditions. We will test the atomization behavior of the waste fuel sprays for a wide range of conditions. The outcome of Activity 2 will be a set of optimized operating parameters for fuel injectors targeting a variety of engine-relevant conditions.

**Activity Milestones:**

Description	Completion Date
Measure rheological properties (density, viscosity, surface tension, etc.) of the waste fuels	June 30, 2024
Design modifications and testing of novel injector for superior atomization (i.e., mist forming behavior)	October 31, 2024
Optimize injector operating parameters specifically for waste fuels	December 31, 2024
Activity 2 summary report	December 31, 2024

### Activity 3: Employ plasma fuel reforming and combustion strategy to improve combustion efficiency and reduce emissions

**Activity Budget:** \$50,000

#### Activity Description:

In this activity, the team will employ two different innovative ignition modules, a) plasma and b) corona ignition strategies to improve combustion performance and emission characteristics of the waste fuels. Both plasma and corona ignition outperform conventional spark ignition systems. Moreover, plasma and corona ignition possess the capability of opening up new chemical pathways for waste fuel to burn. The oxidation pathways of the fuel can be altered to minimize pollutant production. In the past, plasma ignition produced negligible NO<sub>x</sub> and unburned hydrocarbon. Our goal for Activity 3 is to demonstrate that plasma and corona ignition can achieve high efficiency and performance.

#### Activity Milestones:

Description	Completion Date
Develop and optimize plasma igniters specific to waste fuel chemistry	March 31, 2025
Perform combustion of waste fuels in an optical 'see-through' constant volume chamber	April 30, 2025
Perform combustion of waste fuels in a 4-cylinder research engine	May 31, 2025
Activity 3 summary report	May 31, 2025

### Activity 4: Perform detailed testing to optimize waste fuels suitable for engine applications

**Activity Budget:** \$35,000

#### Activity Description:

In this activity, we will perform a detailed campaign testing waste fuels in the engine and engine-relevant conditions. First, selected waste fuels will be tested in an optical 'see-through' combustion vessel. We will use high-speed photography and laser measurements to investigate the chemical kinetics and combustion dynamics of these fuels. We will create a database containing fuel composition, physical properties, emissions, flame speed, ignition delay of waste fuels and optimize the fuels to downselected 2-3 promising fuels for engine testing. Then we will test these 2-3 fuels in a 4-cylinder plasma ignited engine for full and part-load conditions. We will measure combustion performance, stability, and emissions. A detailed test campaign will be carried out to find out the most promising waste fuel. Finally, we will utilize chemical modeling tools to model the chemical kinetics of waste fuel combustion.

#### Activity Milestones:

Description	Completion Date
Complete additional field testing, if necessary	April 30, 2025

### Activity 5: Reporting, results dissemination, and journal paper writing

**Activity Budget:** \$20,000

#### Activity Description:

This phase of the project will focus on the final data analysis and report writing. In addition to meeting the deliverable requirements of the LCCMR Fund, the project team will prepare manuscripts for submission to peer-reviewed journals and will communicate the results of the project with the energy companies and waste management entities. Our final goal is to find a cost-effective, low-carbon waste fuel that will power the off-road transportation and energy sector of Minnesota for decades to come.

#### Activity Milestones:

Description	Completion Date
Finished drafting the first version of the journal/conference article	March 31, 2025
Complete analysis of waste fuel engine testing data	March 31, 2025
Activity 3 summary report	April 30, 2025
Final project report	June 30, 2025

## Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Vinod Srinivasan	Mechanical Engineering, University of Minnesota	Dr. Vinod Srinivasan is an assistant professor of Mechanical Engineering, is an expert in two-phase flow and heat transfer, focusing on liquid atomization, boiling, and evaporation; his research serves as the link that enables the transfer of viscous fuels to engine conditions.	Yes
Roger Ruan	Bioproducts and Biosystems Engineering, University of Minnesota	Dr. Roger Ruan is a professor of BBE, is a recognized world leader in the waste fuel catalytic process. He has an extensive publication record demonstrating improvement in fuel production while reducing processing steps allowing for a wide range of feedstocks ranging from municipal solid waste to biomass/agricultural waste.	Yes

## 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 work be funded?**

Project results will be communicated with the energy and waste management industry and other stakeholders via conferences, journal articles, reports, and direct communication. The impact of this project will influence strategic planning activities of waste management and clean energy stakeholders as they develop the next generation of environment-friendly technologies. The US Department of Energy and the Minnesota Pollution Control Agency are committed to reducing the environmental impacts of landfill wastes and fund research aimed at this goal. Future proposals for funding will be submitted to these sources, as well as by establishing partnerships with private energy and waste management companies.

## Project Manager and Organization Qualifications

**Project Manager Name:** Sayan Biswas

**Job Title:** Assistant Professor

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

Prof. Sayan Biswas, Benjamin Mayhugh Assistant Professor of Mechanical Engineering, is an expert in clean energy, LiDAR sensing, and novel laser-based sensing and diagnostics, will lead this project. PI Biswas has utilized LiDAR to solve challenging problems including the detection of bald eagles and snow particles for self-driving cars. Besides LiDAR sensing, PI Biswas has extensive experience developing optical sensors for energy applications. His research has received support from the Department of Energy (DOE), Advanced Projects Research Agency-Energy (ARPA-E), National Science Foundation (NSF), and several clean energy companies. He manages an annual research portfolio of \$1.6M. Before joining the University of Minnesota in 2020, Dr. Biswas spent 3+ years at the Sandia National Laboratories and 5+ years at Purdue University, working on clean energy and developing advanced light/laser sensing systems. To date, PI Biswas has published 20+ journal articles, 40+ conference articles, 1 single-authored book, 6 book chapters, and holds 1 US patent. PI Biswas leads a highly diverse research group consisting of 6 PhD, 3 MS, and 8 UG students. His lab actively participates in educating the community about our energy future and in K-12 outreach activities, inspiring the next generation of scientists and engineers, and providing an open and equitable learning atmosphere for women, minorities, and indigenous students. Prof. Biswas serves on several technical and advisory committees, volunteering for his professional societies and local Minnesota-based organizations.

**Organization:** U of MN - College of Science and Engineering

**Organization Description:**

The University of Minnesota, Twin Cities is a public land-grant research university in the Twin Cities of Minneapolis and Saint Paul, Minnesota, and one of the most comprehensive research universities in the nation. The University leadership acknowledges that the University of Minnesota Twin Cities is built within the traditional homelands of the Dakota people. It is the flagship institution of the University of Minnesota System and is organized into 19 colleges, schools, and other major academic units. The University advances Minnesota state and US society through new ideas, technologies, treatments, and cures, and continues to create and transfer technology to companies for the development of new products and services that benefit the public good and foster economic growth. The University's College of Science and Engineering received \$141.9 million in research funding in FY2015. The University of Minnesota College of Science and Engineering (CSE) ranks #4 in the country for the best bachelor's degree in engineering. In other rankings, CSE majors traditionally rank among the top 20.

## Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	\$ Amount
<b>Personnel</b>								
Sayan Biswas		Principal Investigator			25%	0.04		\$7,265
Vinod Srinivasan		Co-Principal Investigator			25%	0.04		\$7,431
Roger Ruan		Co-Principal Investigator			25%	0.04		\$9,871
Research Assistant		Graduate Student			43%	3		\$160,477
							<b>Sub Total</b>	<b>\$185,044</b>
<b>Contracts and Services</b>								
							<b>Sub Total</b>	-
<b>Equipment, Tools, and Supplies</b>								
	Tools and Supplies	Fuel, wiring supplies, spray injector, plasma igniter, plumbing parts, chemicals, etc.	Detailed test campaign to optimize waste fuels, their spray characteristics and combustion performance					\$3,956
							<b>Sub Total</b>	<b>\$3,956</b>
<b>Capital Expenditures</b>								
		Pressure and temperature sensor, fuel quality measurement, and waste-to-fuel efficacy estimation	Measure waste fuel properties, efficacy, spray performance, and combustion behavior					\$11,000
							<b>Sub Total</b>	<b>\$11,000</b>
<b>Acquisitions and Stewardship</b>								
							<b>Sub Total</b>	-
<b>Travel In Minnesota</b>								
	Miles/ Meals/ Lodging	Two people to one domestic conference per year	Present the work in a domestic conference, knowledge dissemination					\$5,000



			and attract potential customers/end-users					
							<b>Sub Total</b>	<b>\$5,000</b>
<b>Travel Outside Minnesota</b>								
							<b>Sub Total</b>	-
<b>Printing and Publication</b>								
							<b>Sub Total</b>	-
<b>Other Expenses</b>								
							<b>Sub Total</b>	-
							<b>Grand Total</b>	<b>\$205,000</b>

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
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## Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
<b>State</b>				
			<b>State Sub Total</b>	-
<b>Non-State</b>				
In-Kind	unrecovered F&A calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	\$79,875
			<b>Non State Sub Total</b>	<b>\$79,875</b>
			<b>Funds Total</b>	<b>\$79,875</b>

## Attachments

### Required Attachments

#### *Visual Component*

File: [f497019b-205.pdf](#)

#### *Alternate Text for Visual Component*

The visual illustrates the challenges with landfill wastes, the missing profit and jobs, and the proposed solution. Three steps - a) production, b) atomization, c) utilization/combustion of waste fuels are shown. Image of a pilot waste fuel production system capable of processing 200 kg of feedstock per day....

### Optional Attachments

#### *Support Letter or Other*

Title	File
UMN SPA Support Letter	<a href="#">28872a94-7b0.pdf</a>
Resynergi - Waste Fuel Startup Company	<a href="#">eedd646c-d94.pdf</a>
Resynergi Startup Story	<a href="#">5865aea9-d89.pdf</a>
UMN Waste Fuel Research	<a href="#">012a50a8-9b8.pdf</a>
PI Biswas Plasma Award - Impact Innovation Award 2022	<a href="#">2c4379ae-b97.pdf</a>
Microwave-Assisted Plasma Catalysis of Waste Fuels	<a href="#">2f656485-e96.pdf</a>

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Does your project have potential for royalties, copyrights, patents, or sale of products and assets?**

Yes

**Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?**

Yes

**Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?**

No

**Does your project include original, hypothesis-driven research?**

Yes

**Does the organization have a fiscal agent for this project?**

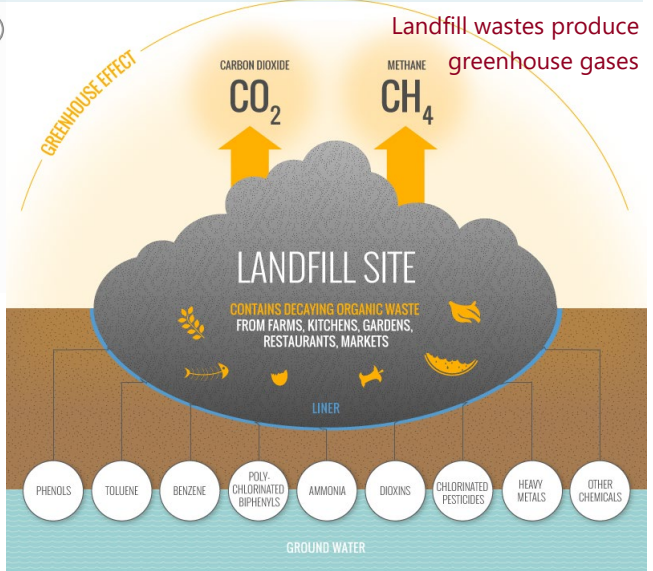
Yes, Sponsored Projects Administration

# Production and Utilization of Fuels from Landfill Waste

Principal Investigator Sayan Biswas, Mechanical Engineering

THE PROBLEM

Nearly 200 million tons of single-use plastics and organic waste goes in landfill every year in the US, a fraction of which is recycled or reused



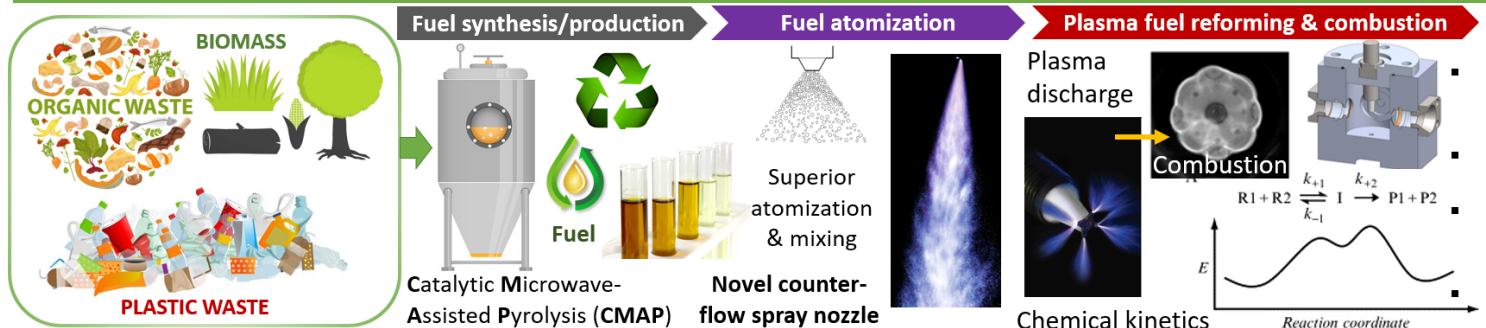
THE OPPORTUNITY

- Recycling creates jobs – nearly 37,000 jobs in Minnesota are supported by this industry, adding nearly \$8.5 billion
- Recycling generates profits – in 2015, Minnesota recycled ~ 2.5 MT of material worth \$690 million
- Insufficient recycling is revenue lost – in 2018, Minnesota spent ~ \$200 million to dispose of 1.2 MT of recyclable material into landfills of an estimated value of \$285 million

Provide the local Minnesota industry with a cost-effective, low-carbon waste fuel that will power the agriculture and energy sector for decades to come

We are proposing innovative technologies to a) **produce** waste fuels by recycling single-use plastics and organic wastes, b) **utilize** the fuels to fit into existing engine architecture, and c) **optimize** the combustion performance and emissions of these fuels.

PROPOSED SOLUTION



Overview of the waste fuel production and utilization technology

IMPACT

- Innovation** – Plastic & bio-waste fuel synthesis & utilization
- Circular economy** – Waste recycling
- Transformative** - Improved efficiency & fuel economy
- Climate action 2030**, Pollution management



We will collaborate with our long-standing industry partners, *Resynergi company* and *Minnesga*, to perform a cost-benefit analysis and identify potential end users and customer base in Minnesota.

A pilot waste fuel production system capable of processing 200 kg feedstock per day.

