Environment and Natural Resources Trust Fund

2025 Request for Proposal

General Information

Proposal ID: 2025-161

Proposal Title: Sustainable Aviation Fuels from Renewables through Microwave-Assisted Conversion

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: This project aims to develop and demonstrate a catalytic microwave-assisted hydrodeoxygenation system for converting waste oils and fats into sustainable aviation fuels.

ENRTF Funds Requested: $898,000

Proposed Project Completion: June 30, 2028

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.

As the government sets its sights on a net-zero emission economy by 2050, the aviation sector's 2-3% share of global carbon emissions becomes a key area for attention. There is an urgent need for substantial breakthroughs in green and sustainable renewable energy to replace fossil-based aviation fuels partially or completely. Sustainable aviation fuels (SAF), derived from diverse sources such as used cooking oil, municipal waste, and renewable feedstocks, have the potential of reducing the lifecycle carbon emissions of flying by over 80%, making them a crucial element in achieving net-zero emissions. Notably, the State of Minnesota stands out as one of the most promising hubs for SAF production, thanks to abundant renewable feedstocks and legislative support in the form of SAF tax credits. In the coming years, we anticipate a rapid growth in the SAF industry in Minnesota.

Despite this opportunity, the current SAF production landscape is not without hurdles. Predominantly relying on ethanol and vegetable oils as feedstocks, coupled with expensive hydrogen and high-pressure conversion processes, the industry faces viability challenges and must confront the challenge of current constraints to achieve broader sustainability goals. This research underscores the necessity of an advanced conversion processes for a greener aviation future.

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.

In response to the critical need for SAF in Minnesota and nationwide to meet ambitious climate targets, the project seeks to pioneer innovative techniques and equipment for the efficient conversion of renewable sources (e.g. used cooking oils and municipal wastes) into SAF within the Minnesota aviation industry. This project aims to develop an advanced catalytic microwave-assisted hydrodeoxygenation process and system to efficiently convert oils and fats into SAF, incorporating polyolefinic plastics as a hydrogen donor. By eliminating the need for costly hydrogen sources and high-pressure conditions during conversion coupled with mitigating the staggering annual generation of waste plastics (400 million tonnes), renewables-to-SAF technology emerges as a comparable or potentially superior alternative to its fossil-based counterpart.

In this project, the initial phase involves assessing the feasibility of converting various waste oils and fats into SAF through the proposed technology. This will be achieved by creating a bench-top scale catalytic microwave-assisted hydrodeoxygenation system, synthesizing appropriate catalyst materials, and optimizing reaction parameters. The outcomes will guide the design of a pilot-scale catalytic microwave-assisted hydrodeoxygenation system for demonstration purposes. Subsequent techno-economic analysis and life cycle assessments will be conducted to expedite the transition to commercialization, maximizing carbon reduction potential of the proposed technology.

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?

This project aims to contribute valuable scientific insights through exploratory research, focusing on two key aspects:

1) elucidating the process of converting waste oils and fats into SAF through catalytic microwave-assisted hydrodeoxygenation without the need for external hydrogen

2) understanding the influence of catalyst structure, temperature, and other variables on SAF production.

Additionally, we'll work towards developing a cost-effective and practical pilot-scale system to demonstrate the feasibility of scaling up. Our collective efforts are poised to accelerate the commercial scaling of SAF in Minnesota, supporting the state-wide airline industry's goal of achieving net-zero emissions for customers by 2050.

Activities and Milestones

Activity 1: Laboratory investigation of converting waste oils and fats into SAF

Activity Budget: $168,000

Activity Description:
Building on our extensive experience in catalytic microwave-assisted pyrolysis for solid waste utilization over the past years, we will design and fabricate an advanced catalytic microwave-assisted hydrodeoxygenation system for converting a wide range of oily feedstocks (used cooking oils, municipal waste scum, and vegetable oils) into Sustainable Aviation Fuels (SAF) at auto pressures, and relatively elevated temperatures (350-450 ºC) within a specified reaction time of 20-60 min. Our preliminary test using waste vegetable oil under the proposed conditions yielded promising results: an aviation fuel product characterized by negligible oxygenates, approximately 80% alkanes (with a carbon chain centered at 8-18), and around 20% mono-aromatics. During the process, polyolefinic plastics will serve as a hydrogen donor, facilitating hydrogenation and deoxygenation. To enhance feedstock conversion and selectively produce desirable chemicals, metal oxides and zeolites will be explored. We will employ a comprehensive suite of advanced analytical techniques to characterize the products from various feedstocks. Additionally, we will determine the optimal process conditions, including the load of microwave absorbents, reaction temperatures, catalyst and plastics loading, and reaction time to maximize SAF yield and quality. Furthermore, we will assess the activity and stability of the selected catalysts, and establish a regeneration protocol during this phase.

Activity Milestones:

Description	Approximate Completion Date
Collect and characterize feedstocks	August 31, 2025
Develop and improve a catalytic microwave-assisted conversion system	December 31, 2025
Conduct experiments on catalytic microwave-assisted hydrodeoxygenation and optimize the process	December 31, 2026

Activity 2: Designing and constructing a pilot-scale demonstration system for catalytic microwave-assisted hydrodeoxygenation

Activity Budget: $530,000

Activity Description:
Following the development and optimization of the bench-top catalytic microwave-assisted hydrodeoxygenation system in Activity 1, we will proceed to design, construct, and demonstrate a pilot-scale system in this phase. Addressing pertinent technical challenges associated with the pilot-scale system, including temperature uniformity, microwave field distribution, and continuous operation, will be a primary focus. The pilot-scale catalytic microwave-assisted hydrodeoxygenation system will undergo rigorous tests to validate the technical and economic viability of the proposed technology at a larger throughput.
This activity aims to optimize the system for enhanced treatment efficiency and reduced environmental impacts under real-world conditions. It will also involve assessing product yield, quality, pollutants/greenhouse gas emissions, and energy consumption, providing crucial data for subsequent techno-economic analysis and life cycle assessment, and demonstrating the system to the stakeholders.

Activity Milestones:

Description	Approximate Completion Date
Design and construction of a pilot-scale catalytic microwave-assisted hydrodeoxygenation system	August 31, 2027
Pilot system improvement and demonstration	December 31, 2027

Activity 3: Conducting techno-economic analysis and life cycle assessment for the proposed technology

Activity Budget: $200,000

Activity Description:

Based on the studies conducted in Activities 1 and 2, we will design end-to-end conversion process and generate data on mass and energy balances, energy consumption and operational costs, and pollutants and greenhouse gas emissions through simulations and measurements for techno-economic analysis and life cycle assessment. In addition, the potential impact of organic gases and aerosols emitted by the system on air quality will be evaluated with continuous monitoring and point measurements.

Activity Milestones:

Description	Approximate Completion Date
Generate information for a techno-economic analysis	March 31, 2028
Monitor pollutants and greenhouse gas emissions for life cycle assessment	March 31, 2028
Final Report on this project with outreach materials	June 30, 2028

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?

To develop a cost-effective and pragmatic pilot-scale catalytic microwave-assisted hydrodeoxygenation system capable of sustainably converting oils and fats into SAF. Collaboration with industry partners will play a crucial role in addressing engineering challenges, providing financial support, and seeking backing from entities such as the Department of Energy (DOE), the United States Department of Agriculture (USDA), and other relevant agencies for further system scaling. This concerted effort is geared towards propelling the technology to a commercial stage. Outreach initiatives will be undertaken to engage airline industry managers with an interest in SAF, fostering opportunities for collaboration and mutual advancement.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Methods to Destroy PFAS in Landfill Leachates	M.L. 2022, , Chp. 94, Art. , Sec. 2, Subd. 04a	$200,000

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 is a Fellow of the National Academy of Inventors, the American Society of Agricultural and Biological Engineers, the Institute of Food Technologists, the International Association of Advanced Materials, and Vebleo, and have received many other awards, including International Bioprocessing Association's Pandey Award, CAFS Professional Achievement, Scientist of IAAM, etc. Dr. Ruan's research areas include renewable energy and environment technologies for sustainable development and circular economy. His research has focused on biomass and solid wastes such as plastic wastes pyrolysis and gasification for chemicals, materials, fuels, and energy production; wastewater treatment and utilization through novel anaerobic digestion, microalgae cultivation; airborne and other pathogen disinfection and pollutant control; innovative catalytic non-thermal plasma, low temperature microwave and pulse microwave, photocatalytic intensive pulse light, and NMR/MRI technologies development and applications in nitrogen fixation, food safety assurance, and food quality improvement; and food engineering and various value-added processing. Dr. Ruan has published over 600 papers in refereed journals, two books, and 28 book chapters, and holds 19 US patents. He is also a top-cited author in engineering and technologies, with an h-index of 96, i10-index of 480, and over 37,000 citations. He has received over 200 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 US patents and licensing of technologies. He has the technical expertise and project management experience to ensure the execution of proposed project.

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

Organization Description:

The Center for Biorefining is a University of Minnesota research center and help coordinate 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 in biobased production technology development; promote technology transfer to industries; and foster

economic development in rural areas. The Center's research programs have been 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.

The Department of Bioproducts and Biosystems Engineering, in CFANS, discovers and teaches solutions for the sustainable use of renewable resources and the enhancement of the environment. We discover innovative solutions to address challenges in the sustainable production and consumption of food, feed, fiber, materials, and chemicals by integrating engineering, science, technology, and management into all degree programs.

https://bbe.umn.edu/biobrief

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Roger Ruan		Principal Investigator			37.1%	0.3		$83,916
Professional Researcher		Manage lab, conduct research and analysis			37.1%	1.5		$134,266
Graduate Research Assistant		Research Assistant			46%	3		$173,637
Post doctoral student		Conduct research and analysis and prepare manuscripts/reports			27.1%	3		$233,386
							Sub Total	**$625,205**
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, PPE including gloves and masks.	For running experiments and operating conversion systems					$23,795
	Equipment	Components for fabrication of a small pilot scale system including microwave assisted 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 of microwave assisted hydrodeoxygenation					$200,000
	Tools and Supplies	2 units computer hardware	Data storage, run analytics, interface with manufactured equipment					$3,000
	Tools and Supplies	components of lab system	For testing and development of lab system					$43,000
							Sub Total	**$269,795**
Capital Expenditures								
							Sub Total	**-**

Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Mileage, per diem for trips for up to the whole team	Collection and transport of feedstock					$3,000
							Sub Total	**$3,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$898,000**

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	**-**

Total Project Cost: $898,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 8a32d1a9-b59.pdf

Alternate Text for Visual Component

The schematic emphasizes the research approach of this project, wherein we aim to convert oils and fats into SAF using our distinctive catalytic microwave-assisted hydrodeoxygenation process. Notably, this process eliminates the requirements for external hydrogen and high pressure....

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
SPA Cover Letter - Aviation Fuel	e43eb6e4-db2.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

No

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

N/A

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

N/A

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

No

Does your project include the pre-design, design, construction, or renovation of a building, trail, campground, or other fixed capital asset costing $10,000 or more or large-scale stream or wetland restoration?

No

Do you propose using an appropriation from the Environment and Natural Resources Trust Fund to conduct a project that provides children's services (as defined in Minnesota Statutes section 299C.61 Subd.7 as "the provision of care, treatment, education, training, instruction, or recreation to children")?

No

Provide the name(s) and organization(s) of additional individuals assisting in the completion of this proposal:

Paul Chen, Juer Liu, Leilei Dai, and Wendy Moylan, University of Minnesota