Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-291

Proposal Title: Electrified Ethanol-to-Jet Fuel for Minnesota

Project Manager Information

Name: Paul Chen

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

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Project Basic Information

Project Summary: Develops a two-step electrified pathway to convert ethanol to lower-carbon sustainable aviation fuel and test whether this process (alternative to conventional refinery) reduce lifecycle emissions and strengthens Minnesota climate resilience.

ENRTF Funds Requested: $300,000

Proposed Project Completion: June 30, 2030

LCCMR Funding Category: Small Projects (G)
    Secondary Category: 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?

Narrative

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

Minnesota is a national leader in corn ethanol production, yet most ethanol is blended into gasoline—a market that has reached saturation and is expected to decline as vehicle electrification accelerates. Without new markets, surplus ethanol capacity could undermine rural economic stability and limit the long-term climate value of Minnesota's renewable fuel investments. Sustainable aviation fuel (SAF) represents a strategic opportunity to redirect Minnesota-produced ethanol into a rapidly growing decarbonization sector. Aviation remains one of the most difficult sectors to electrify, making low-carbon liquid fuels essential. However, existing alcohol-to-jet (ATJ-SPK) technologies convert ethanol through three separate steps—dehydration, oligomerization, and high-pressure hydrogenation—followed by an additional step of blending with externally produced aromatics to meet fuel density and material compatibility requirements. These refinery-style systems operate at high temperature and pressure conditions, with limited compatibility to be electrified by renewable power. This proposal advances a next-generation ATJ pathway by consolidating processing into two electrified modules: microwave-assisted catalytic conversion, and atmospheric pressure non-thermal plasma hydrogenation. The two-step platform is designed to directly produce fully formulated SAF, including aromatics, while replacing conventional thermal heating and high-pressure hydrotreating with more energy-efficient electrified processes aligned with Minnesota's clean energy transition.

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.

This project develops and demonstrates a two-step, fully electrified ATJ conversion platform tailored to Minnesota's ethanol infrastructure. It replaces conventional three-step refinery-style processing with two electrified and integrated modules: microwave-assisted acidic ethanol conversion and non-thermal plasma (NTP)–assisted hydrogenation. The project will quantify greenhouse gas reductions, electricity demand, and overall energy efficiency to determine whether electrified ATJ pathways provide net environmental benefits under Minnesota-specific conditions.

The first module integrates dehydration, oligomerization, and controlled aromatization to convert ethanol into C8–C16 hydrocarbons containing balanced olefins and monoaromatics, eliminating the need for separate aromatic blending. Microwave-responsive catalysts enable more efficient and selective conversion under less severe bulk conditions.

The second module uses NTP-assisted hydrogenation to upgrade olefinic intermediates under near-ambient bulk conditions, replacing conventional high-temperature, high-pressure hydrotreating. Plasma-generated reactive hydrogen species in a synergetic-zone plasma–catalyst configuration selectively saturate olefins while preserving aromatics.

The project will validate reaction performance, quantify product distributions, evaluate energy efficiency, and assess scalability. Life-cycle assessment and techno-economic analysis will quantify greenhouse gas reductions, electricity demand, capital intensity, and cost competitiveness relative to conventional ATJ pathways. By electrifying both catalytic steps, this platform establishes a modular, lower-carbon ATJ pathway compatible with renewable electricity and Minnesota's clean energy economy.

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 advances Minnesota's climate and renewable energy goals by enabling production of SAF from in-state agricultural corn ethanol using electrified catalytic processes powered by renewable electricity. Outcomes include:
(1) quantified greenhouse gas emissions (gCO_2e/MJ SAF) for electrified ethanol-to-jet pathways under Minnesota conditions;
(2) measured energy consumption and comparison to conventional ATJ processes;
(3) identification of conditions under which electrified pathways reduce lifecycle emissions; and
(4) a decision-support framework evaluating feasibility of integrating SAF production with Minnesota's ethanol and

renewable electricity systems.
These results will inform whether electrified SAF production can contribute to Minnesota’s climate and energy goals.

Activities and Milestones

Activity 1: Microwave-Assisted Acidic Conversion of Ethanol to SAF Precursors

Activity Budget: $132,000

Activity Description:

In conventional ATJ systems, ethanol is first dehydrated to ethylene in one reactor and then transferred to a second, pressurized oligomerization unit to build carbon chains, followed by downstream hydrogenation and aromatic blending. These discrete operations require intermediate compression and separation and high-pressure conditions, increasing process complexity and cost. In contrast, this activity will develop an intensified process that directly converts ethanol into jet-range hydrocarbon precursors by consolidating dehydration, oligomerization, and controlled aromatization within one reactor operating under much less severe conditions.

This will be achieved through microwave heating combined with microwave-responsive acidic zeolite catalysts. For instance, H-ZSM-5 catalysts incorporating selected metal cations (e.g., Fe, Ga, Ni) enable localized energy coupling at active sites, promoting C–C coupling reactions without uniformly heating the reactor bulk. Hierarchical porosity will be introduced to improve mass transport and catalyst lifetime. Reaction conditions (temperature, space velocity, microwave power density) and catalyst properties (Si/Al ratio, acidity, pore architecture, metal loading) will be systematically tuned to maximize carbon efficiency and selectivity to the target product of C8–C16 hydrocarbons with balanced olefins and 15–25% monoaromatics to satisfy jet fuel specifications without additional aromatic blending.

Activity Milestones:

Description	Approximate Completion Date
Synthesize and characterize ≥8 microwave-responsive H-ZSM-5 catalysts	June 30, 2028
Complete a thermal vs microwave comparative dataset with ≥95% carbon balance closure and quantified	June 30, 2028
Demonstrate ≥55% carbon selectivity to C8–C16 hydrocarbons containing 15–25% monoaromatics	March 31, 2029
Achieve ≥50-hour stable microwave operation, quantify energy intensity, and deliver validated mass and energy	September 30, 2029

Activity 2: NTP–Assisted Selective Hydrogenation

Activity Budget: $105,000

Activity Description:

Olefin hydrogenation in conventional ATJ systems is achieved through thermal hydrotreating at 250–400 °C and 30–80 bar H_2. While effective, these conditions require high-pressure infrastructure and may over-hydrogenate aromatic compounds that are necessary to meet jet fuel specifications. This activity will develop an NTP–assisted hydrogenation module that activates hydrogen at near-ambient bulk temperature and pressure, generating reactive species such as atomic H and vibrationally excited H_2 to enable selective olefin saturation while preserving aromatics in the presence of catalysts.

A synergetic two-zone plasma–catalyst configuration will be developed to decouple hydrogen activation from surface-mediated hydrogenation selectivity. In the plasma discharge zone, thin metal catalyst films will be used to enhance plasma–surface interactions and promote reactive hydrogen species generation. In the adjacent post-discharge region, supported catalysts, e.g., Pd/Al_2O_3, $Ni–Mo/Al_2O_3$, will facilitate selective olefin hydrogenation. SAF precursors produced from Activity 1 will serve as feedstock to quantify olefin conversion, aromatic retention, hydrogen utilization efficiency, and specific energy input. Plasma diagnostics, including optical emission spectroscopy and electrical measurements, will correlate discharge behavior and hydrogen-species generation with catalytic outcomes to establish structure–function–selectivity relationships guiding scale-up of the electrified, low-severity hydrogenation module.

Activity Milestones:

Description	Approximate Completion Date
Commission NTP reactor; demonstrate ≥80% olefin conversion with ≥90% aromatic retention under near-ambient bulk conditions	June 30, 2028
Demonstrate selective hydrogenation of SAF precursors and quantify hydrogen utilization efficiency and specific energy input.	December 31, 2028
Achieve ≥20% improvement in olefin selectivity compared to thermal hydrotreating and complete durability testing	September 30, 2029

Activity 3: Techno-Economic Analysis (TEA) and Life-Cycle Assessment (LCA)

Activity Budget: $63,000

Activity Description:
This activity will quantify the economic viability and environmental performance of the proposed electrified two-step ATJ pathway using experimentally derived data from Activities 1 and 2. A process model will be developed to integrate microwave-assisted ethanol conversion and NTP-based hydrogenation into a modular plant configuration compatible with Minnesota ethanol facilities. Mass and energy balances will be constructed using measured conversion, selectivity, hydrogen utilization efficiency, and electricity consumption (kWh/kg product). Capital and operating costs will be estimated using equipment sizing, reactor power demand, catalyst replacement rates, and hydrogen supply assumptions, with comparison to conventional ATJ-SPK configurations. A cradle-to-grave life-cycle assessment will be conducted to quantify greenhouse gas emissions (gCO_2e/MJ SAF) relative to conventional jet fuel and thermal ATJ pathways. The analysis will incorporate Minnesota-specific grid carbon intensity scenarios, potential renewable electricity sourcing, and hydrogen production pathways. Sensitivity analysis will evaluate the influence of electricity price, catalyst lifetime, plant scale, and aromatic co-production on cost and carbon intensity. The outcome will be a quantified roadmap identifying cost drivers, carbon reduction potential, and scalability thresholds for deployment within Minnesota's SAF value chain.

Activity Milestones:

Description	Approximate Completion Date
Develop integrated process model for both electrified modules and establish conventional ATJ-SPK benchmark	September 30, 2029
Quantify preliminary greenhouse gas emissions (gCO_2e/MJ SAF) and capital/operating costs	December 31, 2029
TEA/LCA report including full sensitivity analysis, cost drivers, carbon reduction potential for MN SAF	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Roger Ruan	UMN	Co-PI	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
Research results from this project will be disseminated through peer-reviewed publications, technical reports, industry engagement, and public outreach to ensure findings benefit Minnesota's renewable energy and aviation sectors. Scientific outcomes, including catalyst performance, product distributions, and energy consumption, will be reported in journals and conferences such as the American Institute of Chemical Engineers (AIChE) and ACS Energy & Fuels. Project data and technical summaries will also be shared with Minnesota stakeholders including the Minnesota SAF Hub and state agencies to support development of the state's sustainable aviation fuel industry.

Industry engagement will occur through technical discussions and briefings with partners such as Gevo and Greenfield Global, both leaders in alcohol-to-jet fuel technologies, to explore how the research outcomes may inform future pilot-scale demonstrations or process development. Results will also be communicated through university seminars, webinars, and outreach activities aimed at informing policymakers, students, and the public about electrified fuel technologies and their potential climate benefits.

All publications, presentations, and outreach materials will acknowledge ENRTF support using the required attribution language and logo in accordance with ENRTF acknowledgement guidelines. Project updates will also be shared via university websites, newsletters, and social media (including tagging @mnenrtf) to ensure accessibility for Minnesota residents.

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 implemented through pilot-scale validation in partnership with Minnesota ethanol producers and SAF stakeholders. Experimental data, LCA, and TEA results will guide scale-up design and investment decisions for modular electrified ATJ deployment. Following project completion, additional engineering development and demonstration will be pursued through federal funding programs (e.g., DOE, USDA), industry cost-share partnerships, and private investment. Intellectual property generated will support commercialization pathways. Continued development will focus on pilot integration at existing ethanol facilities to enable scalable, renewable electricity–driven SAF production in Minnesota.

Project Manager and Organization Qualifications

Project Manager Name: Paul Chen

Job Title: Research Professor and Program Director

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Paul L. Chen is a Research Professor and Program Director at the Center for Biorefining, Department of Bioproducts and Biosystems Engineering, University of Minnesota. With over 28 years of experience in biomass conversion, waste

valorization, sustainable fuels, and advanced thermochemical processes, he has pioneered catalytic microwave-assisted pyrolysis, hydrodeoxygenation, and biorefining technologies. His extensive research portfolio includes 260+ peer-reviewed journal articles, 15 book chapters, and two books, amassing over 26,800 citations (h-index: 85, i10-index: 237). His expertise in microwave-assisted waste-to-fuel conversion, catalyst development, and resource-efficient recycling has driven key innovations in renewable energy. Holding 18 U.S. patents, Dr. Chen has developed novel technologies in microwave-assisted biofuel production, catalyst design, and pollutant control. His breakthroughs in hydrodeoxygenation have significantly reduced reliance on costly hydrogen and high-pressure conditions for fuel upgrading, making sustainable aviation fuel and waste-to-energy solutions more economically viable.

Dr. Chen has secured over $45 million in research funding from agencies such as USDA, DOE, DOD, and NSF, leading multi-institutional and industry-collaborative projects. His leadership has enabled the scaling of renewable energy and waste mitigation technologies, including the development of pilot-scale microwave-assisted systems for biofuel production and electronic waste recycling. His expertise in techno-economic analysis and life-cycle assessment ensures that projects are scientifically rigorous, financially viable, and environmentally sustainable.

Beyond academia, Dr. Chen actively collaborates with industry to commercialize waste-to-energy and sustainable fuel technologies. He has played a key role in technology transfer, licensing agreements, and industry partnerships, ensuring real-world applications of his research. His service as an editor, peer reviewer, and committee member in multiple scientific organizations further solidifies his influence in shaping the future of renewable energy and waste conversion research.

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 affiliated with the College of Food, Agricultural and Natural Sciences and helps coordinate the University efforts and resources to conduct exploratory fundamental and applied research and provide education on science and technology for environment protection and circular economy; 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								
Professor/Faculty		PI - contract faculty (funding dependent) - lead the overall project and coordinate development of the electrified ethanol-to-SAF platform, supervising reactor development and integration, coordinating experimental work across activities, overseeing analysis and reporting, and ensuring project milestones and deliverables are met.			36.6%	0.6		$25,011
Professor/Faculty		Co-PI - 9 month appointment (2 weeks summer salary) - lead development of the microwave-assisted catalytic conversion platform, catalyst design, microwave reactor experimentation, reaction optimization, and mentoring research personnel.			36.6%	0.15		$37,533
Postdoctoral Researcher		Conduct experimental work for both catalytic modules, including catalyst synthesis, operation of microwave and plasma reactors, reaction optimization, and product characterization. The researcher will also generate datasets used for techno-economic analysis and life-cycle assessment.			26.1%	1.5		$124,917
Graduate Research Assistant		Assist with catalyst preparation, reactor operation, sample preparation, and analytical measurements. The student will also support data processing and integration into system modeling for TEA and LCA analysis.			24.2%	0.75		$47,082
							Sub Total	**$234,543**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								

	Equipment	Microwave-compatible quartz reactor tubes and fittings	Reactor vessels for microwave-assisted catalytic ethanol conversion experiments						$3,800
	Equipment	SiC microwave absorbers / susceptors	Materials enabling efficient microwave energy coupling and localized catalytic heating.						$4,600
	Equipment	Catalyst holders and reactor inserts	Supports for zeolite catalysts during microwave-assisted ethanol conversion testing.						$3,400
	Equipment	Gas flow controllers and calibration hardware (2 units)	Precise control of ethanol vapor, hydrogen, and carrier gas flows during catalytic reactions.						$4,800
	Equipment	Temperature, pressure, and microwave power sensors	Monitoring of reaction conditions for catalytic conversion experiments.						$4,200
	Equipment	Dielectric barrier discharge plasma reactor components	Hardware required to construct the non-thermal plasma hydrogenation reactor.						$4,600
	Equipment	High-voltage probes and electrical diagnostics (2 units)	Electrical monitoring of plasma discharge behavior and energy input.						$4,800
	Equipment	Electrodes and dielectric discharge tubes	Core reactor components enabling plasma generation for hydrogen activation.						$3,900
	Equipment	Liquid feed pumps and ethanol delivery hardware	Controlled feeding of ethanol to catalytic reactor systems.						$2,900
	Tools and Supplies	Chemicals, catalyst precursor materials (zeolites and metal salts), reaction solvents, ethanol feedstock materials, process gases (H_2, N_2), analytical consumables (GC/GC-MS columns, standards, vials), and general laboratory consumables (glassware, tubing, filters, PPE)	Required for catalyst synthesis, catalytic conversion experiments, and product analysis.						$28,457
								Sub Total	**$65,457**
Capital Equipment									
								Sub Total	-
Acquisitions and Stewardship									
								Sub Total	-
Travel In Minnesota									

							Sub Total	**-**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$300,000**

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: $300,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: e9e7d10d-a56.pdf

Alternate Text for Visual Component

This figure illustrates a proposed electrified ethanol-to-SAF pathway for Minnesota. Bioethanol is converted into jet-range hydrocarbons through microwave-assisted catalytic upgrading that integrates dehydration, oligomerization, and aromatization, followed by non-thermal plasma hydrogenation for selective olefin saturation. The approach simplifies conventional ATJ-SPK processing while leveraging Minnesota's ethanol and renewable energy infrastructure....

Supplemental Attachments

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

Title	File
Gevo Letter of Support	e81b686d-8d1.pdf
Greenfield Global Letter of Support	5f2c593d-aa4.pdf
Letter of Approval to Submit	b36fd5cb-db2.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

N/A

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

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?

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:

Wendy Moylan, Department Finance and Riana Fletcher, Sponsored Projects Administration

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

N/A