Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-464

Proposal Title: Enhancing Biodiesel Blend Limits Using Waste Oil-Derived Additives

Project Manager Information

Name: Prasanth Kumar Sasidharan Pillai

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

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Project Basic Information

Project Summary: This project converts waste cooking oil into novel additives that prevent biodiesel crystallization at −30 °C to −40 °C, enabling higher biodiesel blend limits for reliable use in Minnesota's cold

ENRTF Funds Requested: $268,000

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?
    During the Project and In the Future

Narrative

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

Minnesota is a national leader in biodiesel production, generating approximately 85.5 million gallons annually. However, cold-weather performance limits biodiesel use in northern climates. Biodiesel consists mainly of fatty acid methyl esters (FAMEs), which crystallize at low temperatures (−30 °C to −40 °C), causing fuel gelling, clogged pipelines, and operational issues in transportation, agriculture, and industry. These challenges restrict biodiesel blend limits during winter months and reduce the reliability of renewable fuels in cold regions. At the same time, significant amounts of waste cooking oil are generated across Minnesota and remain underutilized. For example, the Minnesota State Fair alone produces an estimated 125,000 to 150,000 pounds of used cooking oil annually. This project addresses these challenges by converting waste cooking oil into novel additives that enhance biodiesel blend limits by improving cold-flow performance. The developed waste oil–derived additives will prevent crystallization at extreme temperatures, enabling higher biodiesel blends while reducing reliance on petroleum-derived additives. By transforming an underutilized waste stream into a high-value fuel additive, the project supports Minnesota's circular economy, improves renewable fuel reliability, and advances sustainable energy adoption in cold climates.

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.

Our proposed solution focuses on enhancing biodiesel blend limits using waste oil-derived additives produced through an innovative metathesis platform. Waste cooking oil (WCO), an abundant and underutilized waste stream in Minnesota, will be converted into high-performance additives that improve biodiesel cold-flow properties and prevent crystallization at temperatures as low as −40 °C. These additives function as pour point depressants, enabling biodiesel blends to remain fluid and operational in extreme winter conditions. Metathesis is a catalytic process that restructures lipid molecules by modifying chain length, branching, and molecular polarity. Through this controlled restructuring, the resulting molecules interfere with biodiesel crystal formation, improving fuel stability and cold-flow behavior. Using this platform, we will develop cost-effective waste oil–derived additives specifically designed to support higher biodiesel blends in cold climates. Two processing pathways will be investigated. In the first pathway, WCO will be converted to fatty acid methyl esters prior to metathesis to allow better control over molecular structure. In the second pathway, metathesis will be applied directly to triglycerides, generating branched derivatives while reducing processing complexity and cost. This scalable approach converts a low-value waste stream into a functional fuel additive that improves biodiesel reliability and supports Minnesota's renewable energy goals.

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 supports the broader utilization of biodiesel across diverse applications by improving its sustainability and reliability in cold climates. By converting waste oil into additives that enhance biodiesel cold-flow properties, the research enables higher biodiesel blend limits and reduces reliance on fossil fuels. This approach promotes waste valorization by converting an underutilized waste stream into a valuable fuel additive. Improved biodiesel performance can reduce emissions and support wider adoption of renewable fuels in transportation and agriculture. By integrating waste utilization with clean energy solutions, the project strengthens Minnesota's economy and contributes to pollution reduction and more sustainable energy systems.

Activities and Milestones

Activity 1: Characterize Waste Cooking Oil (WCO) for Development of Biodiesel Cold-Flow Additives

Activity Budget: $60,000

Activity Description:

Characterizing waste cooking oil (WCO) is a critical first step in developing waste oil-derived additives that enhance biodiesel blend limits. WCO will undergo comprehensive chemical and physical analysis to determine its suitability as a precursor for cold-flow improving additives. Gas chromatography (GC) will be used to determine fatty acid composition, including saturated and unsaturated fractions that influence biodiesel crystallization behavior. Fourier transform infrared spectroscopy (FTIR) will assess oxidation products and polymerized compounds, while nuclear magnetic resonance (NMR) spectroscopy will evaluate triglyceride structure and degradation levels. Differential scanning calorimetry (DSC) will analyze crystallization onset temperature and thermal behavior relevant to biodiesel cold-flow performance. Viscosity and density measurements will further indicate compatibility with biodiesel blends. Contaminant screening, including water content, free fatty acids, and trace metals, will ensure WCO suitability for conversion into functional additives. These analyses will guide purification and modification strategies to produce effective waste oil-derived additives capable of improving biodiesel cold-flow properties and enabling higher biodiesel blend limits in cold climates.

Activity Milestones:

Description	Approximate Completion Date
Collection and preprocessing of waste cooking oil (WCO)	September 30, 2027
Comprehensive chemical and physical characterization of WCO	October 31, 2027
Triglyceride structure and degradation analysis using NMR	October 31, 2027
Thermal behavior and crystallization analysis using DSC	October 31, 2027
Fatty acid composition and oxidative stability analysis using GC and FTIR	October 31, 2027

Activity 2: Fractionation of Waste Cooking Oil to Produce Precursors for Biodiesel Cold-Flow Additives

Activity Budget: $60,000

Activity Description:

This activity focuses on fractionating waste cooking oil (WCO) to obtain lipid fractions suitable for developing additives that enhance biodiesel blend limits by improving cold-flow properties. Chromatographic separation and controlled crystallization approaches will be used to isolate fractions enriched in low-melting, unsaturated components that can act as effective precursors for biodiesel cold-flow additives. Dry crystallization will selectively remove high-melting components through controlled cooling and subsequent filtration or sedimentation. To improve separation efficiency and purity, solvent-mediated crystallization will also be employed to reduce viscosity and enable more precise fractionation. The resulting fractions will be analyzed to determine their suitability for additive development. Gas chromatography (GC) will determine fatty acid composition, while Fourier transform infrared spectroscopy (FTIR) will assess oxidation products and chemical functionality. Nuclear magnetic resonance (NMR) spectroscopy will evaluate triglyceride structure and integrity. Differential scanning calorimetry (DSC) will be used to determine crystallization onset temperatures and thermal behavior relevant to biodiesel cold-flow performance. By optimizing fractionation conditions, this activity will generate WCO fractions enriched in desirable molecular structures that can be further converted into waste oil-derived additives capable of preventing biodiesel crystallization and enabling higher biodiesel blend limits in cold climates.

Activity Milestones:

Description	Approximate Completion Date
Optimization of WCO fractionation to obtain precursors for biodiesel cold-flow additives	January 31, 2028
Composition analysis of fractionated WCO to determine fatty acid profile and structural characteristics	March 31, 2028
Evaluation of thermal and rheological properties of fractionated WCO relevant to biodiesel cold-flow performance	April 30, 2028

Activity 3: Formulation of Waste Oil-Derived Blends for Biodiesel Cold-Flow Additive Development

Activity Budget: $35,000

Activity Description:

This activity focuses on formulating optimized waste oil-derived blends to enhance their suitability for developing additives that improve biodiesel cold-flow properties and enable higher biodiesel blend limits. Fractionated and non-fractionated waste cooking oil (WCO) will be blended with soybean oil at 10–50% levels to adjust unsaturation and molecular composition. Increasing unsaturation can reduce crystallization tendency and improve compatibility with biodiesel fuels. The blended oils will undergo comprehensive characterization to determine their suitability as precursors for cold-flow additives. Gas chromatography (GC) will determine fatty acid composition, while Fourier-transform infrared spectroscopy (FTIR) will assess chemical functionality and oxidation products. Nuclear magnetic resonance (NMR) spectroscopy will evaluate triglyceride structure and molecular interactions. Differential scanning calorimetry (DSC) will analyze crystallization onset and melting transitions relevant to biodiesel cold-flow behavior. Physical properties including viscosity, density, and oxidative stability will also be evaluated. Through systematic evaluation of these formulations, the most effective waste oil-derived blend will be identified as a precursor for additive development, supporting the production of functional additives that prevent biodiesel crystallization and enable higher biodiesel blend levels in cold climates.

Activity Milestones:

Description	Approximate Completion Date
Optimization of WCO–soybean oil blends (10–50%) to enhance unsaturation and additive precursor properties	August 31, 2028
Chemical and structural characterization of blended oils (fatty acid composition, molecular integrity)	August 31, 2028
Chemical and structural characterization of blended oils (fatty acid composition, molecular integrity)	August 31, 2028

Activity 4: Cross and Self Metathesis Modification of Waste Oil Blends to Produce Biodiesel Cold-Flow Additives

Activity Budget: $83,000

Activity Description:

This activity focuses on converting optimized waste cooking oil (WCO)–soybean oil blends into high-performance additives that enhance biodiesel blend limits by improving cold-flow properties. Cross and self-metathesis reactions will be used to restructure lipid molecules and produce compounds that function as effective pour point depressants (PPDs). Metathesis enables controlled modification of chain length, branching, and molecular distribution, which disrupts fatty acid crystallization in biodiesel at low temperatures. Self-metathesis will be optimized to generate symmetrical and asymmetrical products with tailored molecular weight and cis/trans distributions that enhance cold-flow performance. Cross-metathesis will incorporate selected olefin co-reactants to modify fatty acid structures, producing branched and shorter-chain derivatives that reduce crystallization tendencies. Catalyst selection and reaction conditions including temperature, pressure, and reaction time will be optimized to maximize conversion efficiency and product stability. Grubbs catalysts will be evaluated for their selectivity and catalytic efficiency. The resulting additives will be evaluated in biodiesel blends to determine improvements in crystallization onset temperature, pour point, and cold filter plugging point (CFPP). This activity will produce scalable waste oil-derived additives capable of improving biodiesel operability in cold climates and enabling higher biodiesel blend levels.

Activity Milestones:

Description	Approximate Completion Date
Optimize self and cross-metathesis reaction parameters to produce biodiesel cold-flow additives	February 28, 2029
Screen olefin co-reactants for cross-metathesis to modify fatty acid crystallization behavior	February 28, 2029
Catalyst selection and reaction optimization for efficient metathesis of WCO–soybean oil blends	May 31, 2029
Evaluate additive performance in biodiesel blends and select optimal formulations	June 30, 2029

Activity 5: Performance Optimization and Validation of Waste Oil-Derived Additives in Biodiesel Blends

Activity Budget: $30,000

Activity Description:
This activity focuses on optimizing and validating metathesis-derived waste oil additives for improving biodiesel cold-flow properties and enabling higher biodiesel blend limits. Metathesized waste cooking oil (MWCO) additives produced in Activity 4 will be incorporated into biodiesel blends and systematically evaluated for performance under low-temperature conditions. These additives modify fatty acid crystallization behavior by introducing branched and modified molecular structures that improve fuel fluidity and reduce wax formation. Biodiesel blends containing MWCO-derived additives will be tested using differential scanning calorimetry (DSC) and ASTM-standard cold-flow tests, including cloud point (CP), crystallization onset temperature (Ton), pour point (PP), and cold filter plugging point (CFPP). These analyses will determine the effectiveness of the additives in preventing crystallization and improving biodiesel operability in cold climates. The most effective additive formulations will be validated in B100, B20, and B10 biodiesel blends to evaluate their ability to support higher biodiesel blend levels without compromising fuel stability. Additional structural and chemical characterization using GC-MS, NMR, and FTIR will confirm additive composition and functionality. This activity will demonstrate the practical performance of waste oil-derived additives and support their potential integration into commercial biodiesel systems.

Activity Milestones:

Description	Approximate Completion Date
Optimization of MWCO additives for biodiesel cold-flow enhancement	December 31, 2029
Biodiesel blending and performance testing in B100, B20, and B10 fuels	June 30, 2030
Evaluation of crystallization behavior and viscosity changes using DSC and ASTM cold-flow tests	June 30, 2030

Project Partners and Collaborators

Name	**Organization**	**Role**	**Receiving Funds**
Johan Ubbink	University of Minnesota	Co-Principal Investigator	Yes
Veluchamy Chitraichamy	University of Minnesota	Co-Principal Investigator	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.
Project results will be disseminated through peer-reviewed publications, conference presentations, stakeholder workshops, and outreach to Minnesota industry and agricultural partners. All dissemination materials will acknowledge support from the Environment and Natural Resources Trust Fund (ENRTF) in accordance with the ENRTF Acknowledgment Guidelines.

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 collaboration with biodiesel producers, fuel additive manufacturers, and industry partners in Minnesota. The developed waste oil derived additives will be validated for cold flow performance and shared with industry stakeholders for pilot scale evaluation and potential commercialization. Findings will be disseminated through technical reports, scientific publications, and industry workshops to support adoption. After project completion, additional optimization and scale up will be pursued through industry partnerships, federal and state funding opportunities, and collaborative research grants. These efforts will support technology transfer, further product development, and integration of the additives into commercial biodiesel formulations.

Project Manager and Organization Qualifications

Project Manager Name: Prasanth Kumar Sasidharan Pillai

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Prasanth Pillai, Assistant Professor in the Department of Food Science and Nutrition at the University of Minnesota, will serve as the project manager and principal investigator. Dr. Pillai has extensive expertise in the development of polyurethanes and polyurethane coatings from a variety of biomaterials. Currently, he leads upcycling-focused research at the Department of Food Science and Nutrition, where his work focuses on transforming industrial co-products and agricultural residues into high-value materials for environmental, agricultural, and food system applications.

His research includes the development of bio-derived polymers, nanocomposites, and functional coatings using renewable feedstocks such as plant fibers, polysaccharides, proteins, and agricultural residues. Notably, Dr. Pillai has been awarded five patents related to polyurethane materials, several of which have progressed toward commercial applications, demonstrating the translational impact of his research in sustainable polymer development.

Dr. Pillai brings over a decade of combined academic and industrial experience in biomaterials, bioprocessing, and sustainable product development. Prior to joining the University of Minnesota, he held scientific leadership roles at

Louis Dreyfus Company, Noblegen Inc., and Mane Kancor, where he led multidisciplinary projects involving process development, material functionality, and technology scale-up.

As project manager, Dr. Pillai will oversee experimental design, supervise research personnel, coordinate project partners, and ensure the timely completion of project milestones related to the synthesis, formulation, and evaluation of waste-derived polyurethane coatings for controlled-release fertilizers.

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

Organization Description:
The College of Food, Agricultural and Natural Resource Sciences (CFANS) at the University of Minnesota is a leading research and education institution dedicated to advancing sustainable food systems, agricultural productivity, and environmental stewardship across Minnesota. CFANS integrates expertise in soil science, water quality, agronomy, food systems, environmental chemistry, and bioproducts engineering to address challenges at the intersection of agriculture and natural resource protection.

CFANS maintains advanced laboratory facilities, field research stations, and environmental monitoring capabilities that support rigorous evaluation of nutrient dynamics, soil health, and watershed impacts. Faculty collaborate closely with farmers, watershed districts, state agencies, and industry partners to develop and implement science-based solutions that reduce nitrogen and phosphorus losses, improve nutrient management, and protect surface and groundwater resources.

Through interdisciplinary research and strong stakeholder engagement, CFANS delivers measurable, data-driven outcomes that align with the Legislative-Citizen Commission on Minnesota Resources (LCCMR) mission to protect and enhance Minnesota’s land, water, and natural resources.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineli gible	% Bene fits	# FTE	Class ified Staff?	$ Amount
Personnel								
Assistant Professor		Principle Investigator			26.7%	0.09		$16,251
Professor		Co-Principal Investigator			26.7%	0.02		$5,165
Assistant Professor		Co-Principal Investigator			26.7%	0.02		$3,726
Postdoc Associate		Research execution for making additive			20.6%	0.8		$64,992
Postdoc Associate		Physical Characterization of additive and biodiesel blends			20.6%	0.8		$64,992
Graduate Student		Execution of the waste oil additive synthesis and characterization			12.9%	1.5		$86,400
							Sub Total	**$241,526**
Contracts and Services								
Laboratory Services	Internal services or fees (uncommon)	Lab services will include analytical techniques such as X ray diffraction (XRD), nuclear magnetic resonance (NMR), and mass spectrometry methods (MS, GC MS, LC MS) to characterize the structure, crystallinity, and composition of metathesized oligomers. Analyses will be performed through institutional core facilities and specialized analytical laboratories.				0		$5,474
							Sub Total	**$5,474**
Equipment, Tools, and Supplies								
	Tools and Supplies	Lab supplies	The requested $21,000 supply budget will support laboratory and experimental activities required to develop and evaluate waste cooking oil (WCO)–derived additives for improving biodiesel cold-flow properties in Minnesota’s cold climate. Supplies will include chemical reagents, catalysts for					$21,000

			metathesis reactions, chromatography materials, solvents, analytical standards, filtration materials, and general laboratory consumables necessary for waste oil characterization, fractionation, chemical modification, and biodiesel performance evaluation. In Year 1, supplies will support the collection, preprocessing, and chemical characterization of waste cooking oil. This phase will require filtration materials, solvents, chromatography supplies, and reagents used for compositional and structural analysis of WCO. Additional materials will support analytical measurements such as GC-MS, FTIR, NMR, and differential scanning calorimetry (DSC) to determine fatty acid composition, molecular structure, and thermal behavior relevant to biodiesel additive development. In Years 2 and 3, supplies will support fractionation, blending, and metathesis modification experiments to generate optimized lipid additives capable of improving biodiesel cold-flow properties. Materials will include reaction catalysts, purification reagents, chromatography consumables, and solvents needed for reaction optimization and product isolation. Additional supplies will support thermal and crystallization analysis of modified additives and performance testing in biodiesel blends, including evaluation of pour point, cloud point, and cold filter plugging point behavior. Across all years, funds will also cover routine laboratory consumables, including glassware, vials, filtration					

			membranes, pipettes, tubing, sample containers, personal protective equipment, and analytical reagents required for lipid characterization, reaction monitoring, and biodiesel testing. These supplies are essential to ensure reliable experimental measurements and reproducible data for evaluating waste cooking oil–derived additives that improve biodiesel performance and support sustainable fuel innovation in Minnesota.					
								Sub Total	**$21,000**
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	**$268,000**

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: $268,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 028c57bd-aa6.pdf

Alternate Text for Visual Component

The visual representation of oil-based additive on biodiesel at -20 Celsius...

Supplemental Attachments

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

Title	File
Letter from Organization	8edeaa6c-f26.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:

Dr. Prasanth K. S. Pillai – University of Minnesota (Principal Investigator and proposal lead)

Dr. Johan Ubbink – University of Minnesota (Co-Principal Investigator)

Dr. Veluchamy Chitraichamy – University of Minnesota (Co-Principal Investigator)

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