Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-368

Proposal Title: Improving Extreme Weather Resilience with Thermally Adaptive Materials

Project Manager Information

Name: Vivian Ferry

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Development of large-area, thermally adaptive architectural materials that improve resilience to extreme and variable weather by reducing energy demands of buildings.

ENRTF Funds Requested: $781,000

Proposed Project Completion: June 30, 2029

LCCMR Funding Category: Resiliency (A)

Project Location

What is the best scale for describing where your work will take place?

Region(s): Metro

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

In the Future

Narrative

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

Extreme weather events create risks to human health and comfort. Keeping homes and businesses cool in the summer and warm in the winter requires significant energy usage; fluctuations and extreme demands overburden our heating and cooling sources. This creates a resiliency problem: outages in natural gas, electricity, or other fuels lead to both a loss of business and unsafe conditions for the occupants.

Local heat islands are particularly problematic. Surfaces like building facades, pavement, and roads elevate local temperatures, leading to high degrees of variation within population centers, and that variability burdens our energy systems. Studies performed by the Metropolitan Council in their Climate Vulnerability Assessment illustrate the extreme variability here in Minnesota: on a single summer day, temperatures within Minneapolis ranged from 78°F - 111°F depending on the exact location. Facilities such as airports also raise the temperature in nearby neighborhoods. There is therefore a need to develop building materials that are both thermally resilient and adaptive, responding to temperature as needed and operating with minimal energy input. This type of material would be inexpensive to integrate into buildings, making Minnesota more resilient to both extreme weather and local fluctuating energy demand.

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 solution is based on passive radiative cooling, a technology that utilizes infrared radiation to beam heat within the local environment to the cold sky. These materials dramatically reduce surface temperatures (by ~10°F) simply by more effectively radiating heat, without requiring input resources. Laboratory-scale approaches to this problem often use carefully engineered, nanopatterned materials called metamaterials that, due to manufacturing challenges, can only be made economically in very small sizes, e.g., a square inch.

Our team in Minnesota has a recent engineering breakthrough that creates high quality nanopatterned materials over large areas, inexpensively and sustainably. Our proposal is to use our unique process to create a thermally adaptive metamaterial containing phase-change materials that regulates the outward flow of radiated heat as needed, providing cooling in the summer and heating in the winter. The material consists of nanostructures embedded in a flexible polymer film. This engineered material is mechanically flexible and transparent to visible radiation, facilitating integration with building facades, windows, and roofs.

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?

A large-area, thermally adaptive architectural material will be developed that improves resilience to extreme and variable weather, with reduced resource demand compared to conventional heating and cooling systems. At the completion of the project, we will have: 1) Assessed the achievable heating and cooling power associated with this material and the associated reduction in Minnesota's energy demand to combat extreme/variable weather conditions; 2) Developed an inexpensive, scalable manufacturing route to create these large-area, nanostructured materials, as well as estimated the costs and generated patents; 3) Identified promising implementations for Minnesota's built infrastructure.

Activities and Milestones

Activity 1: Design and fabrication of thermally-adaptive materials

Activity Budget: $339,605

Activity Description:
Thermally adaptive metamaterials will be designed using finite element simulations (Task #1). The radiative properties of the final design depend on the shape of the individual nanostructures and their proximity to one another. We will vary shape, composition, and layering of materials using electromagnetic simulations to arrive at designs that exhibit high transparency in the visible and broadband emissivity over a broad spectral range of the infrared, and incorporate phase-change materials to dynamically change the emissivity to adapt to real needs. The design will focus on layered nanostructures of silica, titania, and phase-change oxides. Task #2 will validate the results of these models using a unique University of Minnesota-developed process. We will use lithographic processing to create molds, and transfer these high-resolution nanofeatures into a flexible PDMS stamp. The stamp then imprints a resist material, replicating the initial master many times. We will deliver functional materials to the nanopatterned polymer entirely additively, which enables low-cost and sustainable manufacturing of large-areas, and translates the initial pattern into a large-scale format. Task #3 will use roll-to-roll processing to translate the designs from Task #2 to large areas (> 10 m2).

Activity Milestones:

Description	Approximate Completion Date
Design of nanostructure shape and materials using finite element models	June 30, 2027
Prototype structures are fabricated (> 1 cm2) based on results of Task #1.	January 31, 2028
Roll-to-roll printing of designer metamaterial structures achieved over large areas (> 10 m2) in the laboratory.	June 30, 2028

Activity 2: Characterization of temperature performance and robustness of fabricated material

Activity Budget: $264,745

Activity Description:
This activity will focus on characterization of the performance of our engineered material. Task #1 will measure absorptivity and emissivity across a broad spectral range matching sunlight (400 nm - 25 µm) using a combination of UV-Vis-NIR spectroscopy and Fourier-Transform Infrared Absorption spectroscopy. These measurements will be compared to the predictive models of Activity 1. Task #2 will measure the temperature changes and heating/cooling power associated with this nanostructured material. We will create a testing setup including thermocouples to measure the temperature reduction for cooling applications, pyranometers to measure the solar irradiation and a hygrometer to measure local humidity. To assess winter performance, similar measurements can be performed in cooler ambient conditions and the temperature measured with the thermocouples. Control measurements will be carefully performed to validate cooling predictions. This will be done with the engineered material applied to various types of surfaces. Task #3 will assess the robustness of our composite material to both weathering and mechanical deformation. We will expose the sample to accelerated weathering conditions including UV radiation, humidity, and temperature cycling, and remeasure the optical properties systematically. Similarly, we will perform bending tests on the material to assess the performance under mechanical distortion.

Activity Milestones:

Description	Approximate Completion Date
Measurement of absorptivity and emissivity across a broad spectral range (400 nm – 25 µm)	June 30, 2028

Measurement of temperature changes from large-area material on various surfaces exhibiting thermal adaptability	January 31, 2029
Measurement of robustness of material to weathering and mechanical deformation	June 30, 2029

Activity 3: Assessment of thermally-adaptive materials for resilience

Activity Budget: $176,650

Activity Description:

This stage will assess our design for performance in Minnesota. We will develop large-scale models to predict the improvement in resilience when this material is incorporated in different environments and types of infrastructure (Task #1). Our model will account for local Minnesota weather conditions (direct vs. diffuse sunlight fractions, temperature, wind conditions). We will investigate different types of buildings and implementations (windows vs. other building facades). We will also account for the influence of nearby structures and ground cover, such as urban vs. rural environments and the impact of snow cover. Combined with our experimental data from Activities #1 and #2, this will allow us to identify the most promising sites to use this technology, and to assess the ultimate impact of this design on resilience for Minnesota communities, including the reduction in required heating/cooling costs (Task #2). Finally, we will engage with Minnesota-based companies including architectural glass manufacturers and sustainable building partners about commercialization (Task #3).

Activity Milestones:

Description	Approximate Completion Date
Large-scale model that assesses temperature changes in different buildings and environments	June 30, 2027
Identification of most promising sites for implementation of radiatively-engineered materials.	June 30, 2028
Demonstration of technology to Minnesota-based window, architectural glass, and sustainable building companies and groups.	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Vivian Ferry	University of Minnesota	Vivian Ferry is an associate professor in Chemical Engineering and Materials Science with expertise in light and thermal management, nanostructure design and modeling, and large-area fabrication. She will serve as the project manager.	Yes
C. Daniel Frisbie	University of Minnesota	C. Daniel Frisbie is a professor in Chemical Engineering and Materials Science with expertise in large-area and scalable manufacturing.	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?

The goal of this project is to demonstrate a low-cost, scalable, and thermally-adaptive material that can be manufactured over large areas and integrated into architectural materials. We will pursue licensing by Minnesota-based manufacturers of windows, architectural glass, or window films. The PI has already communicated with several of these companies about light management strategies for architectural materials. The work in this project will generate patents and inform manufacturability.

Project Manager and Organization Qualifications

Project Manager Name: Vivian Ferry

Job Title: Associate Professor

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

Vivian Ferry is an associate professor in the Department of Chemical Engineering and Materials Science at the University of Minnesota. She is an expert in nanostructured optical materials, advanced fabrication, and optoelectronic devices, and leads a research group that uses both experimental and simulation-based techniques to address challenges in light and thermal management. She has published more than 70 scientific articles and delivered over 120 invited talks and seminars on her work, and has collaborated extensively with both academia and industry. For the past 8 years, PI Ferry has taught a course to senior undergraduate Materials Science and Engineering students, connecting students to mentors from local industry to develop technological solutions and assess their economic potential.

PI Ferry has considerable leadership experience with multi-investigator teams and currently leads an interdisciplinary research group of the National Science Foundation-funded UMN Materials Research Science and Engineering Center. She co-leads a College of Science and Engineering initiative on Flexible Electronics and Photonics. She also has management experience, and is currently serving as the Director of Graduate Studies for Materials Science & Engineering at the University of Minnesota Twin Cities.

Organization: U of MN - College of Science and Engineering

Organization Description:

The University of Minnesota is a world-class university and the flagship institution of Minnesota, with more than 50,000 students and nearly 5000 academic staff. Research expenditures in FY 2023 totaled over $1.35B, ranking 12th in the United States among public research universities. The University's technology transfer activities are also highly ranked, ranking in the top 20 public research universities across 5 metrics including new patent applications, deals, disclosures, and license income, as facilitated by the University of Minnesota Technology Commercialization office. Within the University of Minnesota, the College of Science & Engineering supports premier research facilities, including the Minnesota Nano Center, a $30M facility for advanced nanofabrication, the Characterization Facility, and the Minnesota

Supercomputing Institute. The Coating Process and Visualization Laboratory contains numerous additional instruments and processing equipment for roll-to-roll coating, printing, drying, and curing of materials.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Vivian Ferry/Associate Professor		Project Manager/Principal Investigator			26.8%	0.12		$29,112
C. Daniel Frisbie/Professor		Co-Investigator			26.8%	0.12		$49,147
Postdoctoral Scholar		Design, fabrication, characterization, and modeling			21%	3		$238,585
Graduate Student/Chemical Engineering and Materials Science		Design, fabrication, characterization, and modeling			41.4%	1.5		$194,539
							Sub Total	**$511,383**
Contracts and Services								
University of Minnesota Minnesota Nano Center	Internal services or fees (uncommon)	Facility fees for characterization and fabrication equipment				-		$92,727
							Sub Total	**$92,727**
Equipment, Tools, and Supplies								
	Tools and Supplies	Reagents, coating supplies, and materials	Cost of materials to create nanostructured metamaterial					$61,890
							Sub Total	**$61,890**
Capital Expenditures								
		Weathering test system	Tests degradation of material exposed to UV radiation, humidity, and temperature cycling	X				$10,000
		Integrating sphere	Measure thermal emissivity in the infrared spectrum	X				$40,000

		Slot die coater for roll-to-roll instrument	Enables dispensing of material into the patterned nanostructures for large-area manufacturing.	X				$10,000
		Outdoor testing system	Assess heating and cooling performance of architectural material, central to Activity #2	X				$25,000
		Roll-to-roll printing equipment	Allow for increased printing speed on roll-to-roll printing line	X				$30,000
							Sub Total	**$115,000**
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	**$781,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		Weathering test system	This equipment is necessary to assess outdoor performance robustness as detailed in Activity #2. **Additional Explanation :** This equipment will be used in Activity #2 to perform accelerated weathering tests throughout the program.
Capital Expenditures		Integrating sphere	The integrating sphere measures the total emissivity of the material in the infrared, as detailed in Activity #2. **Additional Explanation :** This equipment measures emissivity, which is the key metric for laboratory performance discussed in Activity #2.
Capital Expenditures		Slot die coater for roll-to-roll instrument	This is central to Activity #1 to create large-area materials. **Additional Explanation :** This will be used throughout the project to create the large-scale materials for testing.
Capital Expenditures		Outdoor testing system	This is central to the proposed project as discussed in Activity #2. **Additional Explanation :** This setup will be used to measure the heating and cooling power of the structures throughout the project, as described in Activity #2.
Capital Expenditures		Roll-to-roll printing equipment	This equipment is central to Activity #1 of this proposal. **Additional Explanation :** This is central to Activity #1, and will be used to print the large-area materials needed for testing.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
			Non State Sub Total	**-**
			Funds Total	**-**

Total Project Cost: $781,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: a7ecba76-e55.pdf

Alternate Text for Visual Component

An adaptive building material that cools in warm weather but retains heat in cool weather....

Supplemental Attachments

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

Title	File
UMN LOS	fd26f4f3-30b.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?

Yes, Sponsored Projects Administration

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:

C. Daniel Frisbie, UMN, Sponsored Projects Office (UMN)

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