Environment and Natural Resources Trust Fund

2027 Request for Proposal

General Information

Proposal ID: 2027-043

Proposal Title: Next-Generation Wind Turbine Towers for State Electrification

Project Manager Information

Name: Benjamin Worsfold

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Our research will investigate causes of observed damage in wind turbine towers and develop next-generation designs, strengthening the resilience of Minnesota's renewable energy infrastructure against extreme weather events.

ENRTF Funds Requested: $272,000

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?
Region(s): Metro

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's clean energy future relies heavily on wind power. However, cracking and damage has been identified at the bases of some existing towers where they connect to the concrete foundation. The exact causes of the damage are not fully understood. Studying existing wind turbine towers and the damage that arises during their service life through the use of detailed computer simulations will allow engineers to identify strategies to improve the strength and resilience of future towers. Every year, more efficient wind turbines are constructed taller and heavier than earlier generations, placing substantially larger forces on the connection points between the tower and the foundation. US design standards are based on limited real-world testing, making it difficult for engineers to identify effective strengthening strategies. In addition, our current approach to solving this problem has been to simply make foundations larger, potentially doing little to fundamentally increase reliability while potentially wasting material. As the towers continue to become larger, unknows about effective foundation design may limit future wind generation potential. Studying and improving wind turbine foundations is essential to increasing the resilience of Minnesota wind energy infrastructure and protecting our air, land, and communities.

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 will investigate the root causes of damage identified in existing wind turbine towers and use that knowledge to develop next-generation turbine foundations with improved resilience to extreme weather events. We will evaluate potential solutions, including optimized foundation shape and size, connection design, and how steel is arranged in the concrete foundation. Since it is not practical to construct full-scale physical towers and destroy them just to study the collapse, advanced computer models will be used as a proven and economical alternative. These models will be informed by available test results and documented failure cases. Conducted in collaboration with two Minnesota-based wind turbine design engineering firms (RRC and Barr), this research will produce design recommendations that can be used in practice to support safer and more resilient next-generation wind turbine towers suitable for future conditions. The research will provide actionable guidance to support engineering decisions that improve the resilience of Minnesota's energy grid.

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?

Project outcomes include identification of structural vulnerabilities contributing to recent wind turbine tower damage and the development of strengthened, next-generation turbine designs resilient to extreme-weather events. Wind energy provides the largest share of Minnesota's renewable electricity, accounting for 76% of renewable generation and approximately 25% of total generation [EIA 2024]. By improving wind turbine resilience, this project will help safeguard reliable, Minnesota-based energy while minimizing material use and construction-related environmental impacts.

Activities and Milestones

Activity 1: Develop a detailed 3D computer model of a real wind turbine foundation subjected to extreme weather events

Activity Budget: $136,000

Activity Description:
Working with Minnesota-based wind turbine design firms RRC and Barr, we will select real-world wind turbines representative of current state-of-the-art construction. Detailed three-dimensional finite-element models of the turbine towers will be developed using the software ATENA. The research team has access to high-performance computing resources and all required software licenses. The model will include the concrete foundation with the steel rebar inside, the surrounding soil, and the steel tower. Simulation data will be stored locally and backed up on secure university cloud storage.

The model will be capable of simulating the key ways that damage develops, including concrete cracking and crushing, steel fracture, up to tower collapse. Individual components will be modeled and validated independently before being integrated into the full system model to ensure accuracy and reliable computer calculations.

The completed digital turbine model will be subjected to simulated extreme weather events, including severe windstorms and tornadoes. Simulation results will be checked for realism to confirm that they realistically capture damage patterns observed in practice. These analyses will identify critical structural vulnerabilities, helping to explain recent wind turbine tower failures and guiding the development of improved and more resilient tower designs.

Activity Milestones:

Description	Approximate Completion Date
Meet with Minneapolis-based turbine design firms and select a representative wind turbine tower	July 31, 2027
Build and validate 3D models of individual tower components	October 31, 2027
Combine individual components into a complete wind turbine model and subject to extreme weather events	August 31, 2028
Validate results match realistic damage patterns observed in practice	December 31, 2028

Activity 2: Explore next-generation wind turbine tower design alternatives by testing strengthening techniques on the 3D wind turbine model

Activity Budget: $136,000

Activity Description:
The validated wind turbine tower model developed in Activity 1 will be analyzed to identify critical structural weaknesses that contribute to severe damage or collapse. These vulnerabilities are expected to concentrate in the foundation system and may include concrete cracking and crushing, steel fracture, and connection failure.

The modeling results will be shared with Minnesota-based wind turbine design firms RRC and Barr. Targeted discussions will be held to develop practical strengthening strategies that balance ease of construction, sustainability, cost, and structural resilience. Candidate improvements may include optimizing the foundation shape and size, optimizing how the steel is arranged, use of higher-strength or more durable materials, and modifications to how the tower connects to the ground.

The validated 3D finite element model will then be updated to evaluate the different strengthening strategies. Each

modified design will be subjected to the same extreme weather event to observe where damage starts and how it spreads. Results will be compared against current European and North American design standards to assess performance relative to accepted practice. The most cost-effective strengthening strategies will be documented and publicized. The findings will be disseminated to industry partners and stakeholders through presentations, peer-reviewed publications, and a graduate thesis.

Activity Milestones:

Description	Approximate Completion Date
Determine critical structural vulnerabilities in the tower	February 28, 2029
Meet with Minneapolis-based turbine design firms to review results and identify practical design improvements addressing	March 31, 2029
Build and run models of the strengthened towers to determine effectiveness of proposed fixes	June 30, 2030
Disseminate results through journal publications, a graduate thesis, and in-person presentations to Minneapolis-based turbine design	June 30, 2030

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Ben Krause PE, Director of Structural Engineering	RRC Power & Energy, LLC	RRC is a Minneapolis-based engineering firm focused on wind turbine tower foundation design and has been involved in about one-third of the installed wind energy capacity in the US (58 GW). We will meet regularly to exchange technical input, share results, and coordinate dissemination efforts.	No
Joel Bahma PE, Vice President and Senior Structural Engineer	Barr Engineering Co.	Barr is a Minneapolis-based engineering firm with over 30 years of experience in wind turbine foundation design. The firm has designed foundations for 78 GW of wind farms operating across the United States, from Hawaii to Massachusetts. We will meet regularly to exchange technical input, share results, and coordinate dissemination.	No

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 shared with engineers, regulators, and energy stakeholders who can directly apply the findings to improve wind energy infrastructure in Minnesota. Dissemination will include peer-reviewed journals, technical reports, design guidance, and presentations to industry partners and standards bodies, including the American Concrete Institute, to support adoption into engineering practice. Data, models, and documentation will be archived and maintained by the University of Minnesota to ensure long-term accessibility. Results will also be integrated into engineering education classes and shared through public-facing avenues to help improve the public perception of wind energy infrastructure. These efforts promote informed decision-making, reduce infrastructure failure risk, and support protection of Minnesota's air, land, and communities.

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?
We will disseminate results through publications, conferences, and meetings with local engineering firms. Our project partners, RRC and Barr, will also help disseminate results. Findings will inform professional practice and engineering education. The results can be rapidly adopted by engineers and shared with regulators and design standards bodies, including the American Concrete Institute, where Dr. Worsfold serves as a voting member. Incorporation into official building rules will ensure long-term impact beyond the project period. This project complements Dr. Worsfold's current research on large-scale sustainable infrastructure solutions and forensic collapse investigations. Additional federal and private research funding is being pursued.

Project Manager and Organization Qualifications

Project Manager Name: Benjamin Worsfold

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Dr. Benjamin Worsfold PE is an Assistant Professor in the Structural Engineering group in the Department of Civil, Environmental, and Geo-Engineering at the University of Minnesota and serves as co-director of the large engineering testing facilities. His research focuses on sustainable solutions for large-scale infrastructure, including full-size structural

laboratory testing, advanced computer analysis, ultra-high-performance concrete, studies of why buildings collapse, and anchoring to concrete. He received his PhD in Structural Engineering, Mechanics, and Materials from the University of California, Berkeley in 2022. With over seven years of experience in detailed finite element simulations using the software ATENA, Professor Worsfold has made significant contributions to the field.

He has extensive experience managing externally funded research from state DOTs, federal agencies, and industry partners, including projects sponsored by the National Institute of Standards and Technology (NIST), MnDOT, WisDOT, the American Concrete Institute, and private-sector collaborators. These projects routinely involve multi-year schedules, multiple graduate and undergraduate researchers, and close coordination with producers, material suppliers, and consulting engineers. He has demonstrated the ability to deliver projects on schedule and within budget while producing high-quality, design-relevant outcomes.

Dr. Worsfold is currently involved with the NIST on the federal investigation into the Champlain Towers South condominium collapse in 2021 in Surfside, FL, contributing expertise on collapse of concrete structures. His work helps understand what went wrong and to develop recommendations aimed at preventing similar tragedies in the future. This collaboration reflects his commitment to using engineering research to improve public safety and strengthen the resilience of the built environment.

He is a member of several American Concrete Institute (ACI) committees, groups that write construction rules, helping develop building codes for resilient structures, including nuclear structures. This engagement ensures that the proposed work is aligned with current and future building code needs.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota (UMN) is one of the largest, most comprehensive, and most prestigious public universities in the United States (http://www1.umn.edu/twincities/01_about.php). The College of Science and Engineering at the University of Minnesota is ranked among the top engineering and science academic programs in the country. The college includes 12 academic departments offering a wide range of degree programs at the baccalaureate, master's, and doctoral levels. Indeed, researchers within the College of Science and Engineering are on the leading edge of finding ways to solve some of the world's greatest problems by developing new forms of environment-friendly energy, designing new medical devices, improving digital and electronic technologies, and developing a strong national infrastructure. The College of Science and Engineering also offers students a rigorous, world-class education tailored to their interests and goals. The Department of Civil, Environmental, and Geo- Engineering (CEGE) at UMN is known for its pioneering work in analytical, computational, and experimental methods. We practice research excellence grounded in rigorous fundamentals for wide-ranging applications.

The PI has access to all of the facilities needed in CEGE to perform the described research.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Benjamin Worsfold, PI		Overall project supervision, simulation design, data analysis, and interpretation.			36.6%	0.3		$56,975
Graduate Student Researcher		Graduate Research Assistant. Will build the 3D computer model of the wind turbine tower and will perform the model calibration and validation, will modify the model to explore next-generation wind turbine design. Will process the data, synthesize findings and results, and determine outcomes.			44.1%	1.5		$183,516
Two undergraduate student researchers		Undergraduate Research Assistants. Will assist graduate student with data collection, model calibration, and data analysis.			0%	0.75		$25,246
							Sub Total	**$265,737**
Contracts and Services								
							Sub Total	**-**
Equipment, Tools, and Supplies								
	Tools and Supplies	Laboratory supplies, services, and analytical costs: Including but not limited to external computer storage, supplies to maintain analytical equipment and perform analysis	External storage will be purchased to back up the large simulation data output. Analytical costs and repair costs are included for upkeep of the equipment required for analysis.					$5,986
							Sub Total	**$5,986**
Capital Equipment								
							Sub Total	**-**
Acquisitions and Stewardship								

							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	Two visits a year to each of the two engineering wind turbine design firms are anticipated. RRC is 20 miles one-way from the UMN campus and Barr is 13 miles one-way from the UMN campus. Rate of 70 cents/mile.	regular meetings with the two local wind turbine engineering design firms will guide the construction of the 3D wind turbine model and design of the next generation wind turbines					$277
							Sub Total	**$277**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$272,000**

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: $272,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: 2f7b4cb5-8b2.pdf

Alternate Text for Visual Component

A photo of a collapsed wind turbine tower and the concrete foundation torn apart with rebar sticking out (no people were injured). An arrow points to an image on the right showing examples of detailed 3D computer models of wind turbines showing foundation damage.....

Supplemental Attachments

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

Title	File
Letter of Support Barr	b340b965-de1.pdf
Letter of Support RRC	87eec6bd-1a7.pdf
UMN Board of Regents' Endorsement	716d8d28-738.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?

Yes, I understand the UMN Policy on travel applies.

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:

NA

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