Environment and Natural Resources Trust Fund

2026 Request for Proposal

General Information

Proposal ID: 2026-296

Proposal Title: A Vertical Axis Wind Turbine for Greater Minnesota

Project Manager Information

Name: Richard James

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: State-of-the-art AI optimization methods are used to design a high efficiency vertical axis wind turbine that is deployed in urban, suburban, exurban and rural Minnesota

ENRTF Funds Requested: $593,000

Proposed Project Completion: June 30, 2029

LCCMR Funding 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.

Climate change is affecting Minnesota natural resources in alarming ways. Native plants and animals are disappearing, record high temperatures are being recorded, and wildfires are appearing with greater frequency. Owing to climate change, the scientifically validated First Street Foundation Wildfire Model rates as in “moderate danger” the whole of the Arrowhead stretching west to Beltrami County, a swath of central Minnesota from Wadena County to the Twin Cities, south to the driftless area. Wabasha County, especially, is in “major danger”. To reverse climate change will require diverse solutions adapted to subareas of Minnesota. While Horizontal Axis Wind Turbines (HAWTs) are highly successful for utility-scale power generation in high wind areas of far southern Minnesota, they are not suited or tolerated for much of Minnesota. Solar farms are also a welcomed technology, but the low levels of power at night and in winter, and the difficulty of removing snow, are problematic.
Using AI methods, we have invented a remarkably efficient Vertical Axis Wind Turbine (https://arxiv.org/html/2501.17886v1) adapted to urban, suburban and exurban areas, not suitable for HAWTs or solar. Our design is by a significant margin the most efficient VAWT in existence (near 40% (validated)).

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 is a highly optimized Vertical Axis Wind Turbine (see whirrlenergy.com and https://arxiv.org/html/2501.17886v1). It overcomes the main disadvantage of other VAWTs (of either Darrieus or Savonius type) by substantially reducing the negative torque produced when the blades or airfoils turn against the wind during part of the cycle. It has been highly optimized using Machine Learning (ML) methods. Together with supercomputer simulations (near 1000 at this time) ML methods have allowed us to systematically modify the geometry (shapes, angles, distances) of the design to achieve maximum power output. Our current design has excellent agreement between simulated and measured power output (see https://arxiv.org/html/2501.17886v1, Fig. 4b). We have seen very recently that improvements are possible with our ML methods from further changes of the geometry. We are seeking funding to complete this optimization, to test our final small-scale models at St. Anthony Falls Laboratory, and, by partnering with the Minnesota Regional Development Commissions, to deploy a limited number of full-scale models to test in representative locations in Minnesota.

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?

Climate change provides the greatest overall challenge to Minnesota natural resources. It must be confronted from a variety of directions. Vertical axis wind turbines (VAWTs) are highly suited to Minnesota climate, landscape, and population density. Horizontal Axis Wind Turbines (HAWTs) have been very successful in far southern Minnesota, but typically contain the critical materials Neodymium, Dysprosium and Cobalt, and solar cells typically contain toxic materials. Our VAWTs do not contain critical or toxic materials, and, generally, VAWTs are less dangerous to birds and bats than HAWTs. Our VAWT blades (the largest component) will be made of recyclable thermoplastic material.

Activities and Milestones

Activity 1: Completion of AI design of our Vertical Axis Wind Turbine

Activity Budget: $95,000

Activity Description:
The final design of our VAWT involves two main activities, design and optimization. It begins with a basic objective (completed) involving the evaluation of all types of existing VAWTs and their advantages and disadvantages. This led to our basic design having a deflector that minimizes the parasitic negative torque present in all other designs. Currently, we are doing Machine Learning (ML) optimization of the geometry of our basic design. This activity involves systematically varying the geometry (shapes, lengths, angles). For each geometry, we will calculate the power output of the VAWT by full 3D simulation involving fluid dynamics (including a turbulence model) and wind-driven rotation of the blades. So far, we have done near 1000 simulations of this type. This gives a high-dimensional database of power output vs. geometry for each geometry. Then, Machine Learning methods automatically predict the power output for geometries not part of the database, with remarkable accuracy. Very recently, we have discovered a significant change of geometry, still covered by our patent application, that gives a further major improvement of the already high power output. Activity 1, carried out by graduate students at UMN, will involve completion of this optimization.

Activity Milestones:

Description	Approximate Completion Date
Design and optimization of the geometry of the VAWT	December 31, 2026

Activity 2: Wind tunnel evaluation of fully optimized VAWT scale models

Activity Budget: $162,000

Activity Description:
We synthesized 1m prototypes by 3D printing of our best design at that time (late summer 2024), and we have carried out tests in the large wind tunnel at St. Anthony Falls Laboratory (see https://arxiv.org/html/2501.17886v1 accepted by J. Applied Mechanics, in press. See Fig. 4). To measure the rotation rate of the blades, we built a laser-based system and we have measured torque using an innovative brake. From our website (whirrlenergy.com) we were contacted in Fall 2024 by Dr. Siu-Yue Tam, Associate Professor of Engineering at University of Northwestern - St. Paul, and subsequently by Prof. Jeff Jeremiason at Gustavus Adolphus, and we have shared our design; they are also printing models and using our design of late summer 2024 in their labs and classes. (We will continue to share our designs with them.) These tests have also validated the scaling laws we use to predict full-scale behavior from tests of smaller models (see Fig. 4b and ref. 11 of the paper cited above). For Activity 2 we will build scale models based of the highly optimized designs that emerge from Activity 1. Activity 2 will begin upon completion of Activity 1.

Activity Milestones:

Description	Approximate Completion Date
Construction of fully optimized scale models	February 28, 2027
Wind tunnel tests on fully optimized scale models	May 31, 2027

Activity 3: Evaluation of MN locations for deployment

Activity Budget: $50,000

Activity Description:
We have contacted all of the Minnesota Economic Regional Development Commissions, and they are advising us on deployment of a fully optimized full-scale model of our VAWT. (As a government agency they cannot directly suggest a location, but they have been an excellent source of local information.) Based on overall interest, enthusiasm and suitability of location, we will begin the process of planning locations for deployment of our final full-scale, fully optimized VAWTs. We will deploy five 3m VAWTs and one 6m VAWT. This will be an ongoing activity following the selection of a final design and verification of our optimized VAWT and scaling laws. We have previously discussed deployment on a UMN campus with Shane Stennis, Systemwide Chief Sustainability Officer of University of Minnesota System. He is open to this possibility with a suitable educational component. We will further investigate a possible deployment on a U of M campus. Our overall goal in the selection of sites is not to compete with HAWTs or solar, but to provide an alternative in locations where these developed technologies are not suited or not allowed.

Activity Milestones:

Description	Approximate Completion Date
Visit and identify most suitable locations for deployment	September 30, 2027
Selection of locations for deployment of full-scale models	December 31, 2027

Activity 4: Design of the generator and control system

Activity Budget: $83,000

Activity Description:
As explained in Activity 2, we have previously designed and used a braking system to measure the power output in our wind tunnel tests at St. Anthony Falls Laboratory.. In the full scale models proposed here, we will need to design a generator, control system, inverter and storage mechanism. While some of these components will ultimately be off-the-shelf, we prefer to design from a basic engineering viewpoint taking into account the quantitative information on our particular VAWT design we have gained from Activities 1 and 2. Our measurements reported in https://arxiv.org/html/2501.17886v1 show a peculiar dependence of power output on rotation rate and wind speed, which can be the basis for controller design. Doing this carefully has educational value and also can make a significant difference in power conversion, as compared to generic off-the-shelf systems. This work will be done by one of the funded graduate students chosen to have expertise in this area. This is a highly developed field in Aerospace Engineering and Mechanics and also Electrical and Computer Engineering at UMN.

Activity Milestones:

Description	Approximate Completion Date
Design and construction of generator and controller	March 31, 2028
Study of regulations and best practices for connecting a VAWT to home and grid systems	April 30, 2028

Activity 5: Construction and deployment of full-scale wind turbines

Activity Budget: $203,000

Activity Description:
This activity concerns the main construction and deployment of the wind turbines. We will construct five 3m turbines and one 6m turbine. Based on the optimization and verification of Activities 1 and 2, and the design of the generator and control system of Activity 4, we will contract to have these components built or we will obtain them off-the-shelf. It is anticipated that the blades will be extruded thermoplastic, the rotors will be off-the-shelf pipes and the end pieces will be moulded. The bearings and gears will be purchased. Some parts of the base will be moulded and others will be 3D

printed. The generator and control system will be based on the findings of Activity 4; it will likely contain a mix of off-the-shelf and assembled parts.

Activity Milestones:

Description	Approximate Completion Date
Deployment of turbines in previously selected locations	March 31, 2028
Construction of five 3m turbines	July 31, 2028
Construction of 6m turbine	August 31, 2028
Testing of turbines	October 31, 2028
Completion of project, summary of findings, reporting	June 30, 2029

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Richard D. JAMES	Department of Aerospace Engineering and Mechanics, UMN	Principal investigator	Yes
Huan Liu	Drinkward Postdoctoral Fellow, Caltech	Co-investigator, AI enabled design and optimization	No
Niyati Panchal	WhirrlEnergy LLC	Investor Relations and Business Developer	No

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 accumulate valuable data that give optimal designs of full scale VAWTs. We will build full-scale models and deploy them in representative locations, guided by the advice of Minnesota Regional Development Commissions. Our particular advantage is high-level engineering design. In the long term, we intend to carry out full-scale commercialization in Minnesota. We have the full support of the Office for Technology Commercialization at UMN. Our longer term goal is to make Minnesota the center of green manufacturing of a highly optimized VAWT for Minnesota and for the 775 million people worldwide with no access to electricity.

Project Manager and Organization Qualifications

Project Manager Name: Richard James

Job Title: Distinguished McKnight University Professor

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

Richard D. James is Distinguished McKnight University Professor in the Department of Aerospace Engineering and Mechanics at the University of Minnesota. With former graduate student Dr. Huan Liu (now Drinkward Postdoctoral Fellow, Caltech), he owns the Minnesota company WhirrlEnergy LLC (whirrlenergy.com). He has an Sc.B. in Engineering from Brown University and a Ph.D. in Mechanical Engineering from the Johns Hopkins University. He has authored or co-authored over 190 articles, with 18,000 citations. He has given 55 plenary/named lectureships, and he was awarded the Humboldt Senior Research Award (2006/7), the Warner T. Koiter Medal from American Society of Mechanical Engineers (2008), the William Prager Medal from the Society of Engineering Science (2008), the Brown Engineering Alumni Medal (2009) and the Theodore von Karman prize from Society for Industrial and Applied Mathematics (2014). In 2019, he received a Vannevar Bush Faculty Fellowship ($3M) for work on the Mathematical Design of Materials; this is the highest academic award of the DoD (approx. (10 awarded per year nationally in all fields of science, engineering and biology). James has also led major US national multidisciplinary projects in areas of materials science, engineering and mathematics. During the past 5 years James has managed the projects and funding for 6 graduate students and 3 postdoctoral fellows. With Huan Liu he has invented, applied for a patent, and optimized (backed up by ~1000 supercomputer simulations) an innovative vertical axis wind turbine (VAWT) using state-of-the-art machine learning methods. This is especially suited for rural, exurban, and suburban areas, where horizontal axis wind turbines would not

be tolerated. Dr. Liu and James have built scale models of this VAWT and have done extensive tests on small scale models at St. Anthony Falls Laboratory.

Organization: U of MN - College of Science and Engineering

Organization Description:
The research and development for the vertical axis wind turbine described here will be supervised by Prof. Richard James. The proposed work includes design, supercomputer simulation, optimization based on machine learning, construction of models, wind tunnel testing at St. Anthony Falls Laboratory, and construction and deployment of full scale models in exurban and rural Minnesota. James is a faculty member in the Department of Aerospace Engineering and Mechanics, which belongs to the College of Science and Engineering. James is 51% owner of the Minnesota company WhirrlEnergy LLC (whirrlenergy.com). His former graduate student Huan Liu (now Drinkward Postdoctoral Fellow at Caltech) is co-owner (49%) . Niyati Panchal (Master of Public Policy, UMN) is Investor Relations and Business Developer for WhirrlEnergy. The Minnesota Supercomputing Institute, of which James is a member, houses exceptional facilities for computational studies which will be used for AI based optimization. For the construction of scaled designs we will make use of an extensive collection of 3D printers available in the College of Science and Engineering, the UMN Medical Devices Center and Medical School as well as the facilities of the Anderson Innovation Labs and the CSE Shop. Full scale models will be built in James' lab.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Principal Investigator		Richard James, Principal Investigator			36.6%	0.24		$112,438
Graduate Research Assistant		Graduate Research Assistant, Department of Aerospace Engineering and Mechanics			23.2%	18		$186,334
Graduate Research Assistant		Graduate Research Assistant, Department of Aerospace Engineering and Mechanics			23.2%	18		$186,334
							Sub Total	**$485,106**
Contracts and Services								
College of Science and Engineering (UMN) machine shop and 3D printing services	Internal services or fees (uncommon)	Machining of structures and sensors, 3D printing				0		$8,530
St. Anthony Falls Laboratory	Internal services or fees (uncommon)	Fees for wind tunnel tests at SAFL as part of Activity 2				0		$2,000
							Sub Total	**$10,530**
Equipment, Tools, and Supplies								
	Tools and Supplies	Blades for construction of VAWTs (five 3m and one 6m)	Sheet stock, bulk parts					$22,400
	Tools and Supplies	Blade supports (for 6 wind turbines)	Supports and joins the ends of the blades					$5,400
	Tools and Supplies	Deflectors (for 6 wind turbines)	Piece with triangular cross-section the deflects wind					$8,125

	Tools and Supplies	Bearings (for 6 wind turbines)	Thrust and cylindrical bearings					$4,050
	Tools and Supplies	Bevel gears (for 6 wind turbines)	Power transmission					$2,674
	Tools and Supplies	Structural supports (for 6 wind turbines)	Supporting structure for blades					$3,560
	Tools and Supplies	Main shafts of rotors (for 6 wind turbines)	The main shafts of the turbines (2 per turbine)					$1,300
	Tools and Supplies	Generator system (for 6 wind turbines)	Electrical generators and associated parts					$3,330
	Tools and Supplies	Control system (for 6 wind turbines)	For control of the generators to achieve maximum power for the wind speed					$3,525
	Tools and Supplies	Rectifiers and converters (6 wind turbines)	To convert the electricity generated to a standard useable form					$10,000
	Tools and Supplies	Storage batteries (for 6 wind turbines)	Storage of electricity during periods of non-usage					$9,000
	Tools and Supplies	Accessories (one each of torque sensor, RPM sensor, SCADA system, mounting fixtures)	For testing of both scale model and final models of wind turbines					$1,500
							Sub Total	**$74,864**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	6 trips, 200 miles/trip, 2 people, 1 night, lodging ($110. per person per day), meals at $68/day, mileage	In-person examination of sites for deployment of wind turbines					$2,400
	Miles/ Meals/ Lodging	6 trips, 200 miles/trip, 2 people, 1 night, lodging ($110/person day), meals ($68/person day), mileage	Preparation of the sites					$2,400
	Miles/ Meals/ Lodging	6 trips, 200 miles/trip, 2 people, 2 nights, lodging ($110/person day), meals ($68/person day), mileage	Deployment of the 6 wind turbines					$4,800
	Miles/ Meals/ Lodging	1 trip, 3 people, 3 days, 2 nights, lodging ($110/person day), meals ($68/person day), mileage	Final examination of the deployed wind turbines at the end of the project by the PI and two students					$900

							Sub Total	**$10,500**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Preparation of sites for deployment	Preparation of 6 sites for deployment. Local contractors will be used. $2000. per site					$12,000
							Sub Total	**$12,000**
							Grand Total	**$593,000**

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: $593,000

This amount accurately reflects total project cost?

Yes

Attachments

Required Attachments

Visual Component

File: b4688df2-fce.pdf

Alternate Text for Visual Component

Letter of support from the University of Minnesota Sponsored Projects Administration...

Supplemental Attachments

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

Title	File
Owners of WhirrlEnergy LLC at SAFL	c3ebd02a-3cc.jpe
SAFL_topview	f0f94186-ec3.png
SAFL_sideview	0a0a1b93-a1b.png
SAFL_frontview	40948612-ad2.png
HL_RDJ_Journal_of_Applied_Mechanics paper	8c735ab8-c29.pdf
UMN Sponsored Projects Support Letter	ae920a70-715.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?

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:

Huan Liu (CalTech), Niyati Panchal (WhirrlEnergy LLC), Josh Gates (UMN), Dennis Nelson (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