Environment and Natural Resources Trust Fund

2023 Request for Proposal

General Information

Proposal ID: 2023-132

Proposal Title: Minimizing Wildlife Collisions with Wind Turbines Using LiDAR

Project Manager Information

Name: Sayan Biswas

Organization: U of MN - College of Science and Engineering

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Project Basic Information

Project Summary: Design improved deterrent technologies to minimize wildlife fatalities at wind facilities by applying a novel sensing technique – LiDAR, enabling a better understanding of bat/bird behavior near wind turbines.

Funds Requested: $500,000

Proposed Project Completion: June 30, 2025

LCCMR Funding Category: Methods to Protect, Restore, and Enhance Land, Water, and Habitat (F)

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?

In the Future

Narrative

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

Wind energy is a cost-competitive, clean energy source that benefits Minnesota. However, an undesirable environmental impact of wind energy installations is the bat and bird fatalities. Attracted by wind turbines, wildlife bats alter their flight course to approach and interact with wind turbines. In contrast, birds are not attracted to wind turbines but can collide unpredictably. 10,000 – 100,000 bats and birds are killed from collisions with wind turbines in North America each year. Although bat mortality patterns and fatality statistics at different wind turbine sites are extensively studied and well-documented, the underlying causes why bats are attracted to wind turbines remain largely unclear. Most existing hypotheses are unverified due to a lack of detailed quantitative information. Existing studies use 2D camera imaging with limited range and cannot accurately estimate height/depth, both being critical to understanding wildlife flight behavior. We will overcome this limitation using long-range light detection and ranging (LiDAR) systems combined with bioacoustics sensing and thermal imaging, providing a precise estimation of the 3D flight paths of wildlife near wind turbines. The project aims to unambiguously determine the underlying causes of bat mortality at wind turbines, enabling the development of better collision risk minimization strategies.

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.

A comprehensive field-testing campaign, every day from sunset to sunrise during a full season of June-October when bats and birds are most active in central Minnesota, will be performed using three sensor systems simultaneously, a) long-range LiDAR, b) bioacoustic sensors, and c) thermal imaging to evaluate hypotheses of flying wildlife and wind energy interactions. LiDAR will precisely estimate the location, attitude, and 3D flight paths of bats and birds. Ultrasonic bioacoustic detectors will be used to identify different bat species. In synchronization with LiDAR and bioacoustic sensing, long-range thermal imaging with passive 3D depth sensing and high-speed infrared imaging will support bat behavior interpretation. This cluster of sensors will be deployed and tested at the University of Minnesota's 2.5 MW wind energy research station in Rosemount, Minnesota. This test site is just 2 miles from the western bank of the Mississippi River and attracts a large number of Minnesota bats, including hoary, big brown, eastern red, silver-haired, and little brown bats, and is in the Mississippi flyway for birds. The proposed LiDAR technology will provide critical insights and flight path prediction capabilities of flying wildlife and wind energy interactions bolstering collision risk mitigation strategies at Minnesota wind farms.

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?

Minnesota wind facilities are responsible for thousands of bat and bird fatalities every year. Minnesota is home to eight bat species, with four listed as Special Concern by the Minnesota Department of Natural Resources, including the northern long-eared bat which is also protected by the Federal Endangered Species Act. Growing demands for clean wind energy threaten the entire bat population, making them critically endangered. This proposed project will provide scientifically rigorous data using LiDAR technology explaining the causes of bat and bird facilities at wind facilities. Findings from this study will help designers build reliable wildlife deterrence or mitigation technologies.

Activities and Milestones

Activity 1: Development, instrumentation, and fusion of sensor systems

Activity Budget: $170,000

Activity Description:
In this activity, the LiDAR, camera imaging, bioacoustics, and data acquisition sensors will be calibrated, tested, and prepared for field testing. In addition to PI Biswas's two Luminar LiDAR systems, three additional LiDAR systems will be acquired for this project with a 500+ meter range and spatial accuracy of less than 1 cm. PI Biswas possesses high-speed cameras and Teledyne FLIR infrared thermal camera that will be synchronized with LiDAR systems. Different LiDAR systems will cover upstream and downstream air space of the wind turbine, blades, and meteorological (met) tower. Co-PI Feist's noise logger, weather station, and a wind speed LiDAR system will be used to monitor the weather conditions and wind speed/directions. WEST, Inc. will acquire/provide 14+ ultrasonic microphones and acoustic detectors to identify bat species.

The centerpiece of the Eolos Wind Energy Research Consortium is the field research station at UMore Park in Rosemount, MN (about 20 miles southeast of the Twin Cities campus). The focal points of the site are a Clipper Liberty 2.5 MW wind turbine and a 130-meter-tall met-tower constructed 170 meters south of the turbine. The sensor system will be deployed at the Rosemount test site and the immediate surrounding area.

Activity Milestones:

Description	Completion Date
Set up and synchronize LiDAR, cameras, and bioacoustic sensors	December 31, 2023
Complete testing of the sensor system in a laboratory setting	February 28, 2024
LiDAR systems capable of detecting bats and birds from 500+ meter distance	April 30, 2024
Activity 1 summary report	May 31, 2024

Activity 2: Comprehensive field testing investigating bat and bird interactions with wind turbine

Activity Budget: $130,000

Activity Description:
A full season, June to October (5 months), when wildlife bats and birds are most active in central Minnesota, will be dedicated to field testing at the University of Minnesota's state-of-the-art 2.5 MW wind energy research station in Rosemount, Minnesota. The common bats encountered in central Minnesota are hoary bat, big brown bat, eastern red bat, and silver-haired bat. Every day during the season, the LiDAR and imaging data will be recorded all night, from sunset to sunrise. LiDAR and cameras will be remotely monitored and will be checked in person on a weekly basis. PI Biswas is currently working on a machine-learning algorithm to develop an automated triggering system to start recording LiDAR and camera data once a bird or bat is detected. This would significantly reduce the manhours to review the data to find bat activities in the LiDAR videos.

A list of hypotheses, predictions, and approaches based on bats and birds will be considered during the field testing. The turbine blade speeds will be varied as possible to understand the effect of turbine operating conditions on bats and birds.

Activity Milestones:

Description	Completion Date
Deploy LiDAR sensing systems for field testing	June 30, 2024
Complete the first field testing campaign	October 31, 2024

Complete analysis of LiDAR data of bats and birds interacting with wind turbine	December 31, 2024
Activity 2 summary report	December 31, 2024

Activity 3: LiDAR data analysis and hypotheses testing

Activity Budget: $100,000

Activity Description:
Once the field testing season is over, our task will be to analyze the enormous amount of data and see how they fit into the following key hypotheses to address why bats are attracted to wind turbines.
H1) Bats are attracted to operating turbines. Blade movement (visual stimulus) or sounds may attract bats.
H2) Bats are attracted to the turbine structure. Bats may see the turbine as the tallest tree, potential roost, or maybe attracted to insect remnants on blades.
H3) Bats use turbines as roosts.
H4) Bats are attracted to modified landscape features.
H5) Migrant or mating bats clump in time and space. Bats may use the turbine as a gathering point.
H6) Bats are attracted to turbines as foraging sites.

The following key hypotheses address why birds collide with wind turbines.
H1) Flying birds do not exhibit collision avoidance behavior near turbines.
H2) Birds flying in flocks are less likely to fly near turbines
H3) Birds flying during light hours are less likely to fly near turbines than birds flying at night.
H4) Bird flight in relation to turbine heading (wind direction) is the same.
H5) Migratory bird flights are predicted by weather fronts.

Activity Milestones:

Description	Completion Date
Complete LiDAR video processing and data analysis	March 31, 2025
Finish testing hypotheses H1 to H6	April 30, 2025
Provide detailed insights based on learnings from analyzed data	May 31, 2025
Activity 3 summary report	May 31, 2025

Activity 4: Additional field testing, if necessary (optional)

Activity Budget: $30,000

Activity Description:
If our team realizes that we need additional field test data towards a specific situation with a specific sensor arrangement, in case a) we did not obtain conclusive results in the first field testing or b) we found interesting bat behavior that requires additional field testing. The same UMore park wind turbine facility will be used to gather a few more weeks' worth of field data in the following season Y2025 between March to May, which covers the spring bat migration time period. If for some reason we do not find enough wildlife activities at the Rosemount wind facility, our backup option is Xcel Energy's Blazing Star wind farm with a 200 MW capacity located in southwest Minnesota's Lincoln County. Xcel energy is extremely supportive and enthusiastic about our project (please see their support letter) and they will partner with us if we are successful in receiving funding.

Activity Milestones:

Description	Completion Date
Complete additional field testing, if necessary	May 31, 2025

Activity 5: Reporting, results dissemination, and journal paper writing

Activity Budget: $70,000

Activity Description:

This phase of the project will focus on the final data analysis and report writing. In addition to meeting the deliverable requirements of the LCCMR Fund, the project team will prepare manuscripts for submission to peer-reviewed journals and will communicate the results of the project to the wind industry as well as companies that produce bat detection and deterrent systems.

Activity Milestones:

Description	Completion Date
Finished writing the first draft of the journal/conference article	March 31, 2025
Complete analysis of LiDAR and video imaging data	March 31, 2025
Activity 3 summary report	April 30, 2025
Final project report	June 30, 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Christopher Feist	St. Anthony Falls Laboratory, University of Minnesota	Christopher Feist has been involved in SAFL and wind energy research on projects ranging from novel wind turbine drivetrains to health monitoring of wind turbine foundations to mapping the hearing abilities of bald and golden eagles. Chris will be in charge of the Rosemount wind turbine operation and sensor development.	Yes
Christopher Milliren	St. Anthony Falls Laboratory, University of Minnesota	Chris Milliren will provide technical support and develop the sensor systems used in examining wildlife-bat behavior near wind turbines.	Yes
Richard Christopher	St. Anthony Falls Laboratory, University of Minnesota	Richard Christopher will provide technical support for the development of the sensor system. Richard is also the safety officer of the research site and will develop safety plans for sensor installation at the wind energy research site.	Yes
Jennifer Stucker	Senior Research Biologist, Western EcoSystems Technology, Inc.	Dr. Jennifer Stucker is an expert in evaluating bat behavior and habitat selection in an ecological context. She has extensive experience using innovative measurement approaches to evaluate natural resources questions. She will help develop the sensor system and evaluate hypotheses. She has prior experience working at the Rosemount wind turbine.	Yes
Kevin Heist	Consulting Biologist, Western EcoSystems Technology, Inc.	Dr. Kevin Heist has a decade of experience in bat acoustic analysis, radar deployment, and analysis of imaging sensors to support bat and migration and ecology questions. He will help deploy the sensor system in the field and provide feedback on our hypotheses.	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?

Our project will help improve deterrent technologies to minimize wildlife bat and bird fatalities with wind turbines based on an in-depth understanding of bat behavior near wind facilities. We will communicate the results of the project with the wind industry and companies that make wildlife detection and deterrent systems. Our LiDAR systems will be able to detect as well as predict wildlife behavior, which can be leveraged to trigger the bat and bird deterrence systems. The impact of this project will influence the strategic planning activities of primary wind energy stakeholders as they develop the next generation of environment-friendly technologies.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Behavioral Response of Bald Eagles to Acoustic Stimuli	M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 07d	$261,000

Project Manager and Organization Qualifications

Project Manager Name: Sayan Biswas

Job Title: Assistant Professor

Provide description of the project manager's qualifications to manage the proposed project.
Prof. Sayan Biswas, Benjamin Mayhugh Assistant Professor of Mechanical Engineering, is an expert in clean energy, LiDAR sensing, and novel laser-based sensing and diagnostics, will lead this project. PI Biswas has utilized LiDAR to solve challenging problems including the detection of bald eagles and snow particles for self-driving cars. Besides LiDAR sensing, PI Biswas has extensive experience developing optical sensors for energy applications. His research has received support from the Department of Energy (DOE), Advanced Projects Research Agency-Energy (ARPA-E), National Science Foundation (NSF), and several clean energy companies. He manages an annual research portfolio of $1.6M. Before joining the University of Minnesota in 2020, Dr. Biswas spent 3+ years at the Sandia National Laboratories and 5+ years at Purdue University, working on clean energy and developing advanced light/laser sensing systems. To date, PI Biswas has published 20+ journal articles, 40+ conference articles, 1 single-authored book, 6 book chapters, and holds 1 US patent. PI Biswas leads a highly diverse research group consisting of 6 PhD, 3 MS, and 8 UG students. His lab actively participates in educating the community about our energy future and in K-12 outreach activities, inspiring the next generation of scientists and engineers, and providing an open and equitable learning atmosphere for women, minorities, and indigenous students. Prof. Biswas serves on several technical and advisory committees, volunteering for his professional societies and local Minnesota-based organizations.

Organization: U of MN - College of Science and Engineering

Organization Description:
The University of Minnesota, Twin Cities is a public land-grant research university in the Twin Cities of Minneapolis and Saint Paul, Minnesota, and one of the most comprehensive research universities in the nation. The University leadership acknowledges that the University of Minnesota Twin Cities is built within the traditional homelands of the Dakota people. It is the flagship institution of the University of Minnesota System and is organized into 19 colleges, schools, and other major academic units. The University advances Minnesota state and US society through new ideas, technologies, treatments, and cures, and continues to create and transfer technology to companies for the development of new products and services that benefit the public good and foster economic growth. The University's College of Science and Engineering received $141.9 million in research funding in FY2015. The University of Minnesota College of Science and Engineering (CSE) ranks #4 in the country for the best bachelor's degree in engineering. In other rankings, CSE majors traditionally rank among the top 20.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Sayan Biswas		Principal Investigator			25%	0.14		$21,794
Richard Christopher		Co-Principal Investigator			25%	0.1		$11,410
Chris Feist		Co-Principal Investigator			25%	0.3		$27,735
Chris Milliren		Co-Principal Investigator			25%	0.1		$10,319
Research Assistant		Graduate Student			43%	3		$162,665
							Sub Total	**$233,923**
Contracts and Services								
Western EcoSystems Technoloy, Inc.	Professional or Technical Service Contract	provides environmental and statistical consulting services and contract research nationally and internationally. WEST offers a unique combination of field ecology and statistics to help solve ongoing and contemporary natural resource problems.				2		$150,000
Vertical Limit	Professional or Technical Service Contract	is a local Minnesota company who will help install the LiDAR and other sensors at the wind turbine and met tower. They are experts in mounting specialized sensors at tall structures.				2		$6,000
							Sub Total	**$156,000**
Equipment, Tools, and Supplies								
	Equipment	thermal imaging camera, sensor mounting	Thermal imaging of wildlife-bats near wind turbines at night					$2,000
	Tools and Supplies	Sensor mounting, lenses, weatherproof box for LiDAR, wiring supplies, plumbing parts, LiDAR maintenance and mechanical parts and fasteners	Tools and supplies (e.g., fasteners, sensor mounting boards, etc.) to add sensors to the turbine and surrounding area					$4,000
							Sub Total	**$6,000**
Capital Expenditures								

		LiDAR systems	LiDAR sensing system to measure the 3D flight path of bats and birds near wind turbines	X				$90,000
		bioacoustic sensors	Bioacoustics will provide us with information about bat species. Bioacoustic signature along with LiDAR sensing will provide the bat's activity near wind turbines.	X				$8,077
							Sub Total	**$98,077**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	a) Travelling to the wind energy test site, weekly 1-3 times for 6 months, b) One trip per year for one PI to a relevant conference	Testing campaign, knowledge dissemination and attract potential customers/end-users					$5,000
							Sub Total	**$5,000**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
	Publication	Publication cost in open source journals	Open source journal let everyone access the research results at free of cost					$1,000
							Sub Total	**$1,000**
Other Expenses								
							Sub Total	**-**
							Grand Total	**$500,000**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request
Capital Expenditures		LiDAR systems	To the author's knowledge, LiDAR sensing has never been used for bat sensing in the field. PI Biswas has been working in this area, wildlife detection using LiDAR for the last two years, and possesses two LiDAR sensing systems. However, for this project, 3 additional systems will be needed. A total of 5 LiDAR systems will be monitoring the wind turbine space simultaneously. This will help us understand and design the bat deterrent systems, which have not been understood and done before. The project's success is entirely reliant on simultaneous measurement of the entire air space using LiDAR. **Additional Explanation :** PI Biswas owns 2 LiDAR systems, 3 more ($25-30k each) will be purchased to cover the entire airspace near the turbines. The sensor system will be mounted on the wind turbine and met tower for monitoring. This capital equipment will be essential for our project that will pay off in two years. After two years, the PI can use these LiDAR and bioacoustic sensors for remediation of bat fatalities purposes. Bats can be detected using LiDAR and bioacoustic sensing, and different deterrent strategies will be used. These sensing systems can also be permanently installed in one of the Minnesota wind firms (e.g., Rosemount, Blazing Star, etc.) after the project life is over.
Capital Expenditures		bioacoustic sensors	Bioacoustic sensing is as important as LiDAR, since when they are combined with LiDAR sensing, a full picture of the flying wildlife, bat and bird behavior around the wind turbine can be understood. **Additional Explanation :** WEST possesses 10 bioacoustic sensors. 14+ additional sensors will be purchased to put across the 1 square mile area to detect the acoustic signature and echolocation from bats to learn which species they are.

Non ENRTF Funds

Category	Specific Source	Use	Status	Amount
State				
			State Sub Total	**-**
Non-State				
In-Kind	unrecovered F&A calculated at 55% MTDC	Support of ME facilities where research will be conducted.	Secured	$193,683
			Non State Sub Total	**$193,683**
			Funds Total	**$193,683**

Attachments

Required Attachments

Visual Component

File: d5b6041c-948.pdf

Alternate Text for Visual Component

The visual illustrates the crisis wildlife bats are facing due to growing wind energy demand in North America and Minnesota. Our proposed solution and its novelty/uniqueness, research team, planned experimental arrangement of LiDAR, bioacoustic sensors, and thermal cameras in the Rosemount wind energy site are described pictorially....

Optional Attachments

Support Letter or Other

Title	File
Xcel Energy Support Letter	fb867543-9ed.pdf
WEST, Inc. Support Letter	f3dc88fc-5dd.pdf
UMN SPA Support Letter	b204ef8f-229.pdf
DOC-EERA Support Letter	bfd0f9f4-38c.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

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

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

Minimizing Wildlife Collisions with Wind Turbines Using LiDAR

Principal Investigator Sayan Biswas, Mechanical Engineering

University of Minnesota Twin Cities

The Problem

Wind turbines pose severe threat to flying wildlife, bats and birds

Wind energy is a cost competitive and clean energy source that offers clear benefits to Minnesota, but poses a risk to wildlife. 10,000 – 100,000 bats and birds die at wind turbines in North America each year. The underlying causes of why bats are attracted to wind turbines remain largely unclear to experts. This prohibits us to develop reliable deterrent technologies or mitigation strategies.

Northern long eared bat as protected under the Federal Endangered Species Act.

Myotis septentrionalis

Proposed Solution

Light **D**etection **A**nd **R**anging – **LiDAR** precisely estimates the 3D flight paths of bats providing a understanding of bat behavior near wind turbines and help us build effective deterrent technologies minimizing collision risks

LiDAR provides critical insights into wildlife bat and wind energy interactions that leads to robust and reliable collision risk mitigation strategies at Minnesota wind farms. LiDAR can also predict bat flight paths enhancing the effectiveness of wildlife bat deterrent systems. We will perform rigorous scientific testing over an entire bat migration season at Eolos Wind Research Station in Rosemount, Minnesota.

Novelty & Uniqueness

LiDAR sensing: Long-range 500+ meter detection capability of bats and their 3D flight course.
Multiple sensor measurement: LiDAR, thermal and visible cameras, and bioacoustic sensors synchronized using an automated trigger signal for remote data collection.
Location: University of Minnesota's 2.5 MW wind energy research station in Rosemount, MN. Test site is just 2 miles from the western bank of the Mississippi river, a high bat activity region.
Wind energy facility: Isolated wind turbine and meteorological tower; ability to control turbine speed and operating parameters.
Machine learning: Advanced machine learning tools to accurately create 3D bat flight paths.

Team

WEST Environmental & Statistical Consultants

Mechanical Engineering

St. Anthony Falls Lab

Supporters

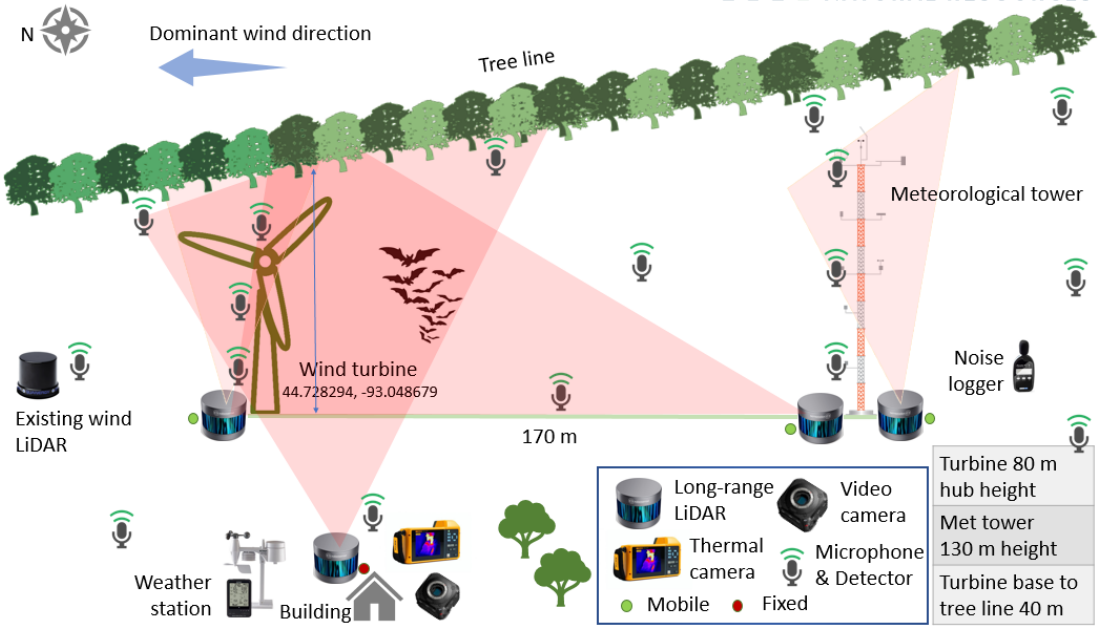
Xcel Energy

LUMINAR

Minnesota Department of Commerce

Department of Natural Resources

Rosemount, MN test site



Arrangement of LiDAR, bioacoustic sensors, thermal and high-speed camera