# Environment and Natural Resources Trust Fund

2021 Request for Proposal

## General Information

**Proposal ID:** 2021-354

**Proposal Title:** Modeling Wind Energy Resources and Environment in Minnesota

## Project Manager Information

**Name:** Lian Shen

**Organization:** U of MN - St. Anthony Falls Laboratory

**Office Telephone:** (612) 624-2022

**Email:** shen@umn.edu

## Project Basic Information

**Project Summary:** We will establish an advanced tool for predicting wind conditions across Minnesota and establish a valuable map for determining suitable sites for wind energy plants, with cold weather accounted for.

**Funds Requested:** $318,000

**Proposed Project Completion:** 2024-06-30

**LCCMR Funding Category:** Foundational Natural Resource Data and Information (A)

## 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.**

Wind power is the third-highest electricity producer in Minnesota, accounting for over 19% of 2019 production. There are currently 3,843 MW of installed wind capacity in Minnesota with another 500 MW under construction. Capital investments in wind energy in Minnesota to date are estimated to be $7.9 billion. In 2019 there were between 2,000 and 3,000 wind industry jobs in MN and 20 active manufacturing sites for wind farm products.

Before developing a new wind farm, detailed screening must be done to ensure the intended location has sufficient wind resources to be financially sustainable. Information like wind speed maps of the state are used to select areas or regions that show promise. Existing state-wide wind maps have relatively low resolution, limiting at around 2.5 km, so wind resources are further investigated at the set of areas chosen to select specific sites. Once these sites are chosen, an in-depth wind analysis must be performed at each site before determining the final site and beginning development. This site-specific analysis lasts a minimum of one year, and often involves the building of large meteorological towers and use of high-end measuring equipment.

**What is your proposed solution to the problem or opportunity discussed above? i.e. What are you seeking funding to do? You will be asked to expand on this in Activities and Milestones.**

This project intends to investigate the patterns of wind energy potential in Minnesota at local scales. The power output of a wind plant varies with the local wind speed, and therefore can cause great uncertainties for utility regulation. Power system operators forecast hourly electrical loads a day in advance to give energy generators time to commit resources. Next-day wind forecasts are used along with load forecasts to find an efficient balance of wind production. Accurate day-ahead weather forecasts are thus critically needed to predict the available wind energy, in order to reduce wind curtailment and maintain high system reliability. Minnesota's unique winter climate can pose a challenge for standard wind power forecasts, as they often do not account for power production losses due to turbine icing or turbine shut-off during extreme cold events.

**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?**

We aim to: 1) develop a computational model to simulate average wind conditions across Minnesota; 2) validate this model using data collected from wind research stations and Minnesota wind farms; 3) use this model to find areas with high wind resources to streamline the wind resource assessment process; 4) modify this model to predict near-future wind resources and other relevant weather conditions at specific sites.

## Activities and Milestones

### Activity 1: Develop modeling tool for predicting wind conditions across Minnesota

**Activity Budget:** $95,400

**Activity Description:**
The Weather Research and Forecasting System (WRF) is a computational weather prediction software. WRF will be used to create a model of average weather patterns over Minnesota. The model will be created using historical data from regional weather observations, and will solve for variables including wind speed, wind direction, temperature, air pressure, and humidity. Data collected from the UMN wind research field station and from industry partners will be used to calibrate the model and ensure model validity. Experiments may also be performed in the St. Anthony Falls Laboratory's wind tunnel to aid in model development and for additional model validation.

**Activity Milestones:**

| Description | Completion Date |
|---|---|
| A comprehensive database of wind speed and direction, air temperature and density in Minnesota. | 2022-12-31 |
| A high-resolution computational model of wind resources across Minnesota. | 2023-06-30 |
| A validation framework to apply to the model using data gathered in Outcome 1. | 2023-09-30 |

### Activity 2: Develop strategies for determining suitable sites for wind farms based on model data

**Activity Budget:** $127,200

**Activity Description:**
A process for determining areas of high wind farm viability will be created. The variables determined most important to wind farm success, such as wind speed and wind direction, will be extracted from the computational model in Activity 1. Maps of wind energy capacity and wind farm viability across the state will be created. Performing this analysis using a model with higher resolution and accuracy is intended to reduce the uncertainty in the initial stages of wind farm siting.

**Activity Milestones:**

| Description | Completion Date |
|---|---|
| An engineering prediction tool to determine areas best suited to wind installations. | 2023-06-30 |
| Maps of high-resolution wind energy capacity and viability for Minnesota. | 2023-12-31 |

### Activity 3: Develop model to allow for near-future predictions of meteorological variables at wind farms

**Activity Budget:** $95,400

**Activity Description:**
The validated WRF computational model from Activity 1 will be modified to allow for short-term weather forecasting. The WRF system is currently used by organizations like the National Centers for Environmental Prediction to perform hourly forecasts across North America for the National Weather Service. A higher resolution forecast model would allow for site-specific estimates of relevant weather patterns and variables. A method of extracting these predictions for a specific wind farm site will be developed, allowing the available wind power at certain sites to be better predicted even in extreme cold conditions.

**Activity Milestones:**

| Description | Completion Date |
|---|---|
| A computational model to predict atmosphere conditions and likelihood of turbine icing across Minnesota. | 2023-12-31 |
| Maps of high-resolution wind energy capacity and viability for Minnesota. | 2024-06-30 |

## 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 be funded?**

This project will be completed within three years. A better understanding of available wind energy in Minnesota will benefit wind farm developments and utility regulation. High resolution data and maps from this study especially will help reduce barriers to entry for local wind farm developers. The ability to perform short-term wind forecasts will be a valuable tool as wind energy continues to grow as an electricity producer in the state.

## Other ENRTF Appropriations Awarded in the Last Six Years

| Name | Appropriation | Amount Awarded |
|---|---|---|
| Extraction of Solar Thermal Energy in Minnesota | M.L. 2017, Chp. 96, Sec. 2, Subd. 07a | $250,000 |
| Assess and Develop Strategies to Remove Microscopic Plastic-Particle Pollution from Minnesota Water Bodies | M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04b | $300,000 |

## Project Manager and Organization Qualifications

**Project Manager Name:** Lian Shen

**Job Title:** Professor and Director

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

Dr. Lian Shen is the Director of the St. Anthony Falls Laboratory and a Professor in the Department of Mechanical Engineering at University of Minnesota, Twin Cities. He earned his Doctor of Science degree from Massachusetts Institute of Technology in 2001. After three years of postdoctoral training at MIT, he joined the faculty of Johns Hopkins University in 2004. In 2012, he was recruited by University of Minnesota to join its faculty. Dr. Shen is a world expert on the study of environmental fluid flows and renewable energy. He is currently serving on the national committee of ASCE Environmental & Water Resources Institute on CFD Applications in Water and Wastewater Treatment. He is also on the editorial boards of four internal academic journals. Dr. Shen has organized several national and international conferences and symposiums, and has participated in a large number of research projects funded by federal and state agencies, including the Minnesota Environment and Natural Resources Trust Fund. On wind energy research, Dr. Shen is currently serving as the Co-Chair of the Advisory Group of the National Offshore Wind Energy Research and Development Consortium, which has 40 organizations nationwide. At University of Minnesota, Dr. Shen has been serving as the Director of the EOLOS Wind Energy Research Center since 2015. Eolos is a university-based center providing research-based collaborations between industry, universities, and governmental agencies that will lead to advances in wind energy technology, new innovation, and long-term expansion of wind energy production.

**Organization:** U of MN - St. Anthony Falls Laboratory

**Organization Description:**

This project will be performed at the St. Anthony Falls Laboratory (SAFL, http://www.safl.umn.edu) at University of Minnesota. SAFL is an interdisciplinary fluid mechanics research and educational institution. It has 22 faculty members and 35 research and administrative staff members. SAFL is a world-renowned research laboratory specialized in environmental and engineering fluid mechanics. SAFL researchers have been performing many innovative environmental studies for the state of Minnesota. Some of the projects were/are funded by the Minnesota Environment and Natural Resources Trust Fund. The proposed research leverages on the unique and advanced

capability of simulating and measuring environmental flows at SAFL, which has 16,000 ft2 of research space dedicated to research. The facility, which has recently been upgraded with a $16M renovation, has a wind tunnel and 15 general purpose flumes, tanks, and channels readily configurable to the needs of the projects.

## Budget Summary

| Category / Name | Subcategory or Type | Description | Purpose | Gen. Ineligible | % Benefits | # FTE | Classified Staff? | $ Amount |
|---|---|---|---|---|---|---|---|---|
| **Personnel** | | | | | | | | |
| Project Manager | | Oversee the whole project and lead the research planning and reporting | | | 27% | 0.12 | | $36,508 |
| Postdoctoral Associate | | Design and establish computational model and carry out computer simulations | | | 20.2% | 3 | | $193,799 |
| Graduate Student Research Assistant | | Perform experiments to validate the computational model | | | 16.6% | 0.75 | | $26,299 |
| Undergraduate Student Assistant | | Assist experiment data analysis and model validation | | | 0% | 0.75 | | $7,200 |
| IT Staff | | Assist computational model development | | | 24% | 0.6 | | $44,809 |
| | | | | | | | **Sub Total** | **$308,615** |
| **Contracts and Services** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Equipment, Tools, and Supplies** | | | | | | | | |
| | Equipment | Cost of two anemometers ($1,000 each), four humidity sensors ($250 each), and data acquisition system ($2,000) | To conduct laboratory and field measurements for validating simulation results. | | | | | $5,000 |
| | Tools and Supplies | Cost of materials for fabricating models to be tested in experiments. | To conduct laboratory and field measurements for validating simulation results. | | | | | $3,635 |
| | | | | | | | **Sub Total** | **$8,635** |
| **Capital Expenditures** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Acquisitions and Stewardship** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Travel In Minnesota** | | | | | | | | |
| | Miles/ Meals/ Lodging | Field experiment | Miles and meals to conduct field experiments | | | | | $750 |
| | | | | | | | **Sub Total** | **$750** |
| **Travel Outside Minnesota** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Printing and Publication** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| **Other Expenses** | | | | | | | | |
| | | | | | | | **Sub Total** | **-** |
| | | | | | | | **Grand Total** | **$318,000** |

## 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** | | | | |
| Cash | National Offshore Wind Research and Development Consortium | The funded project entitled "High-fidelity simulations and data-driven models with turbine controls for the design of bottom-fixed wind farm layouts" will be leveraged on to collaborate with the project proposed here. | Secured | $281,965 |
| In-Kind | Unrecovered F&A | Support of SAFL facilities where research will be conducted. | Secured | $174,900 |
| | | | **Non State Sub Total** | **$456,865** |
| | | | **Funds Total** | **$456,865** |

## Attachments

### Required Attachments

*Visual Component*

File: fd4a689b-58c.pdf

*Alternate Text for Visual Component*

This project aims to modeling the wind energy resources and environment in Minnesota. Minnesota plans to generate all electricity with carbon-free sources by 2050, while wind is leading renewable source. Accurate wind forecasts are needed to plan power production for reliable electricity generation. Existing state-wide wind resource maps have low resolution for site-specific estimates. Cold winter climate poses a challenge for standard wind power forecasting. This project will establish an advanced tool for predicting wind conditions across Minnesota and establish a valuable map for determining suitable sites for wind energy plants, with cold weather accounted for.

## Administrative Use

**Does your project include restoration or acquisition of land rights?**

No

**Does your project have patent, royalties, or revenue potential?**

No

**Does your project include research?**

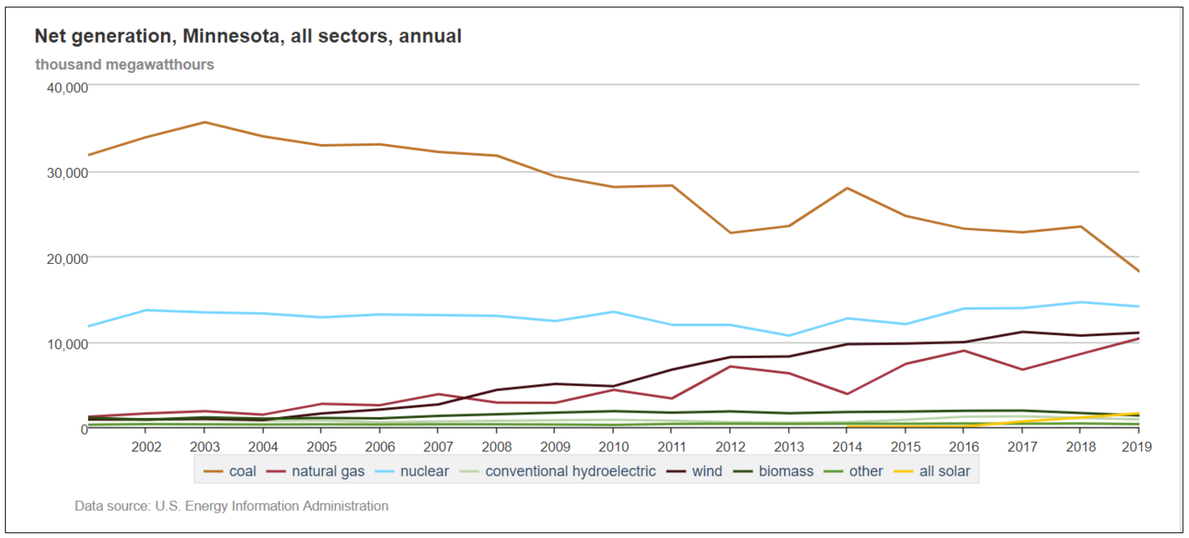
Yes

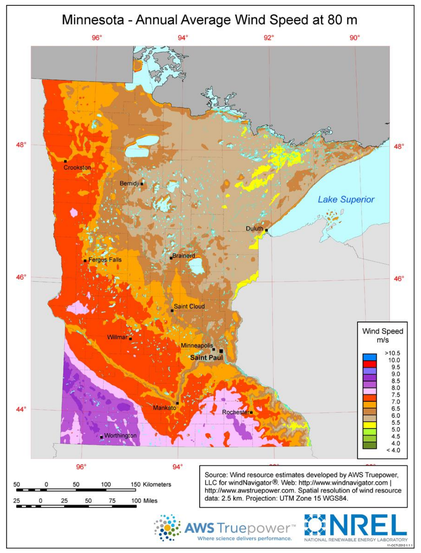
**Does the organization have a fiscal agent for this project?**

Yes, Sponsored Projects Administration

# Modeling Wind Energy Resources and Environment in Minnesota

## Motivation



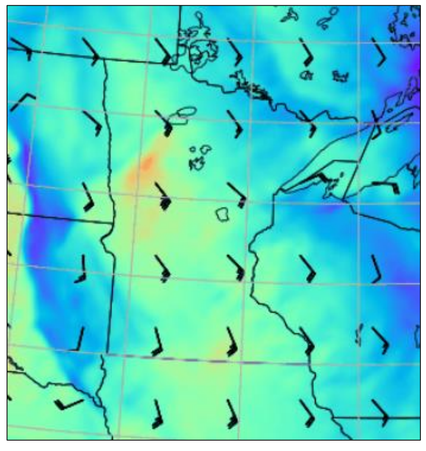



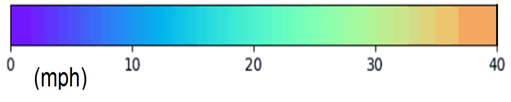


Minnesota plans to generate all electricity with carbon-free sources by 2050, while wind is leading renewable source. Accurate wind forecasts are needed to plan power production for reliable electricity generation.

Existing state-wide wind resource maps have low resolution for site-specific estimates.
Cold winter climate poses a challenge for standard wind power forecasting.

## Plan

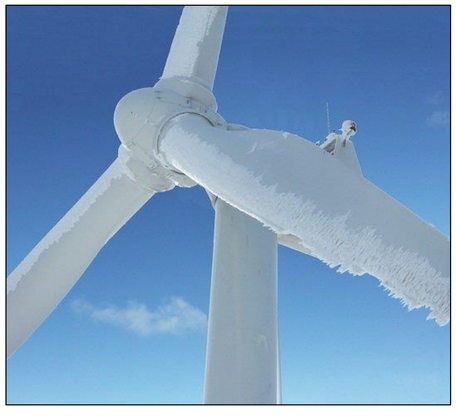





**Models of wind and weather patterns**

predict

validate



**Data from experiments and industry partners**

## Expected outcomes

- Model to find local wind energy patterns in Minnesota for wind farm siting.
- Model capable of predicting next-day wind resources and possible impacts from climate or environment.