Environment and Natural Resources Trust Fund
2019 Request for Proposals (RFP)

Project Title: **ENRTF ID: 195-EH**

Wind Plants Interaction with Local Climate in Minnesota

Category: H. Proposals seeking $200,000 or less in funding

Sub-Category: E. Air Quality, Climate Change, and Renewable Energy

Total Project Budget: $ 199,584

Proposed Project Time Period for the Funding Requested: June 30, 2022 (3 yrs)

Summary:

This project will develop a cutting-edge tool to assess potential environmental costs/benefits of wind plants through an interdisciplinary fusion of laboratory- and field-scale studies as well as computer simulations.

Name: Sung Goon Park

Sponsoring Organization: U of MN

Title:

Department: St. Anthony Falls Laboratory

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Web Address

Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

The images show: 1) wind plants interaction with the surrounding environments including farms and lakes, 2) research facilities at SAFL for performing the project, and 3) expected outcomes.

_____ Funding Priorities	_____ Multiple Benefits	_____ Outcomes	_____ Knowledge Base
_____ Extent of Impact	_____ Innovation	_____ Scientific/Tech Basis	_____ Urgency
_____ Capacity Readiness	_____ Leverage	_____ TOTAL	_____%
____ If under $200,000, waive presentation?			

PROJECT TITLE: Wind Plants Interaction with Local Climate in Minnesota

I. PROJECT STATEMENT

Wind plants are growing rapidly in Minnesota.
Wind power has become one of the main energy sources in Minnesota, accounting for nearly 18% of the total electricity production. Utility-scale wind plants are growing rapidly in both size and numbers. For example, four new wind plants are slated to be built in Freeborn County, Lincoln County, and Pipestone County, and will be operated by the end of 2020 in Minnesota.

How do wind plants interact with local climate?
Wind turbines enhance air mixing by their rotational motion, causing heat and moisture exchanges between air at high altitude and near ground.

Why is this important?
Because there are many farms and lakes in Minnesota, the wind turbine-induced heat and moisture exchange may affect the local climate to impact farm productivity and lake ecology. For example, the turbulent air flows behind wind turbines promote the evaporation of nearby lakes and enhance the oxygen concentration in the lakes through the elevated reaeration at the lake surfaces. A warm air overlying a cool air may be convected down by wind turbines, which may protect crops from frost during night-time. Therefore, an accurate and comprehensive understanding of the impacts of wind plants on local climate is essential and urgent, given the geographical conditions of Minnesota and the rapid growth of wind power in the state.

Objectives
The objectives of this proposal are: 1) to assess the impacts of wind plants on local climate, 2) to create local maps visualizing the wind plants-induced heat and moisture transport, and 3) to develop a predictive tool for optimizing the design and operation of wind plants from a climate perspective. In achieving these goals, the impact of wind plants on the surrounding natural environments will be analyzed.

Strategy to achieve objectives
SAFL has excellent experimental environments for fusing computational, laboratory-, field-scale studies on wind turbines. Laboratory and field studies will be performed in the SAFL wind tunnel and EOLOS wind station, respectively, to investigate the wind turbine-induced heat and moisture transport. A computer simulation tool will be developed based on the laboratory and field measurements data to analyze the wind plants interaction with local climate and to assess their impacts on the surrounding environments. The detailed procedures to achieve the goals are as follows: 1) Measuring air temperature and humidity behind wind turbines at the SAFL wind tunnel test section and EOLOS wind station; 2) Developing a high-accuracy prediction tool that enables the simulation of the heat and moisture transport near wind plants; 3) Investigating the three largest wind plants in Minnesota (Buffalo Ridge, Fenton, Nobles Wind Plants) from a climatic point of view and modifying the prediction tool to consider the surrounding environment; 4) Creating a local map indicating the heat and moisture transport near the wind plants.

II. PROJECT ACTIVITIES AND OUTCOMES

Activity 1: Laboratory measurements in the SAFL wind tunnel
SAFL is equipped with an atmospheric-flow wind tunnel to measure and control air and surface temperatures. The heat transfer near the wind turbine models will be measured in the wind tunnel. The wind tunnel will be upgraded to install humidity sensor, thereby measuring the moisture transport near the wind turbines. The laboratory measurement data will be combined with the field data obtained from the EOLOS wind station.

ENRTF BUDGET: $58,734

Outcome	Completion Date
*1. **A unique dataset of air velocity, temperature, and moisture** near wind turbines under different wind velocity conditions.*	*June, 2020*

Activity 2: Developing a tool (phase I) for the simulation of heat and moisture transport near wind plants

SAFL is equipped with a computational tool (phase I) that enables the representation of the air flow fields near wind plants. The simulation tool has the ability to compute the heat and moisture transport near wind plants under different wind velocity conditions. The simulation tool will be calibrated and validated by comparing to laboratory and field measurements data. A theory that explains the mechanism of how wind plants interact with local climate will be proposed and validated based on dataset collected from laboratory and field measurements as well as computer simulations.

ENRTF BUDGET: $64,776

Outcome	Completion Date
*1. **An engineering tool (phase I)** to simulate the momentum, heat, and moisture transport of air near wind plants.*	*Dec, 2020*
*2. **A new prediction tool** that describes how wind plants interact with local climate.*	*Mar, 2021*

Activity 3: Redesigning a computational tool (phase II) to consider the ambient environments of wind plants

A new version of the computational tool (phase II) will be developed to take into account the geographical conditions of the wind plants in Minnesota. The air velocity, temperature, and humidity strongly depends on the environments, which, thus, should be included in the new simulation tool. Localized map indicating wind plants-induced heat and moisture transport will be created together with an environmental report for the wind plants. A specific guideline for site suitability evaluation of future wind plants from a climatic perspective will be provided based on the map and report.

ENRTF BUDGET: $76,074

Outcome	Completion Date
*1. **An upgraded tool (phase II)** to simulate the momentum, heat, and moisture transport of air near wind plants under different wind speeds and geographical conditions.*	*Oct, 2021*
*2. **Local maps indicating wind plants-induced heat and moisture transport.***	*Mar, 2022*
*3. **Environmental assessment of the potential costs and benefits** of wind plants from a climatic point of view.*	*June, 2022*

III. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

B. Partners NOT receiving ENRTF funding

IV. LONG-TERM- IMPLEMENTATION AND FUNDING:

This project is scheduled to be completed within three years in accordance with the activities and completion dates listed above. It will contribute to assessing potential environmental costs and benefits of wind plants from climatic perspectives. The local maps produced in this project will help the public in Minnesota understand how wind plants can cause changes in heat and humidity. This will serve as a catalyst for public interest and participation in energy and environment. The engineering tool developed in this project will not only offer guidelines for wind power developers to optimize the location and operations of wind plants, but also help the state establish wind power policies and regulations.

V. TIME LINE REQUIREMENTS:

This project will require 3-year efforts starting on July 1, 2019 and ending on June 30, 2022.

2019 Proposal Budget Spreadsheet

Project Title: Wind plants interaction with local climate in Minnesota

IV. TOTAL ENRTF REQUEST BUDGET: 3 years

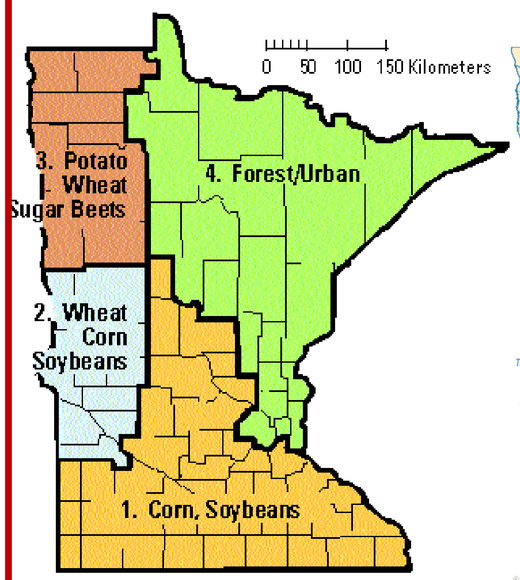
BUDGET ITEM	AMOUNT
Personnel:	$ 186,084
Dr. Sunggoon Park, Project Manager (82% salary, 18% benefit); 50% FTE for each of 3 years. ($95,683)	
Co-investigator Lian Shen (75% salary, 25% benefit); 4.2% FTE for each of 3 years. ($32,464)	
Postdoctoral Associate, experiment and modeling research (82% salary, 18% benefit); 12.5% FTE for each of 3 years. ($23,919)	
IT Research Staff, data analysis and model development (75% salary, 25% benefit); 10% FTE for each of 3 years. ($26,818)	
Undergraduate Assistant, measurement and data analysis (100% salary); 1.5 months for each of 3 years. ($7,200)	
Professional/Technical/Service Contracts: N/A	$ -
Equipment/Tools/Supplies: Cost of setting up of wind turbine models to test in the lab ($3,000), setting up of humidity sensors in the wind tunnel ($3,000), setting up of temperature control and measurement devices ($2,000), and the purchasing of velocimetry ($4,000) for the air flow measurement in this project.	$ 12,000
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel: Tranportation within Minnesota state for field data collection and research meetings with other researchers in the state. Estimation of cost for 3 years: Mileage $0.545/mile x 1000 miles =$545; Incidental expense during travel $200; Lodging $755.	$ 1,500
Additional Budget Items: N/A	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 199,584

V. OTHER FUNDS *(This entire section must be filled out. Do not delete rows. Indicate "N/A" if row is not applicable.)*

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ To Be Applied To Project During Project Period: N/A	$ -	N/A
Other State $ To Be Applied To Project During Project Period: N/A	$ -	N/A
In-kind Services To Be Applied To Project During Project Period: The University of Minnesota does not charge the State of Minnesota its typical overhead rate of 54% of the total modified direct costs (graduate tuition and equipment are excluded).	$ 107,775	Secured
Past and Current ENRTF Appropriation:	$ -	N/A
Other Funding History: N/A	$ -	N/A

Wind Plants Interaction with Local Climate in Minnesota

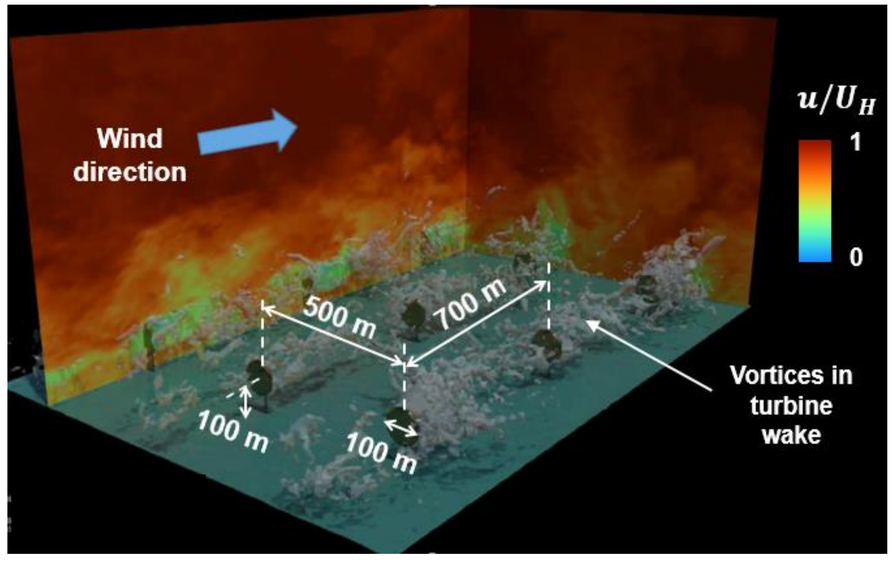
Motivation

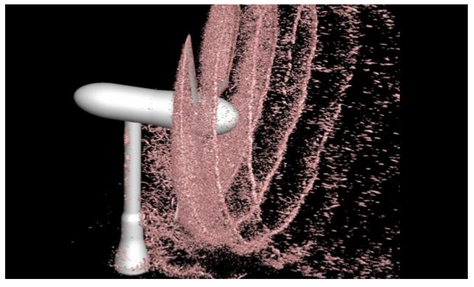


Since Minnesota is widely covered by agricultural farms and lakes, …

… the wind plants-induced heat and moisture transport may have significant impacts on the surrounding environments to affect crop productivity or lake ecology.

Plan





Developing a tool to study the heat and moisture transport near wind plants based on laboratory and field measurements and computer simulations, …

Expected outcomes

… can assess potential environmental costs and benefits of wind plants.

PROJECT MANAGER QUALIFICATIONS

The proposed research will be led by Dr. Sung Goon Park as the Program Manager. Dr. Park obtained his Ph.D. in Mechanical Engineering at Korea Advanced Institute of Science and Technology (KAIST). He performed research in fluid-flexible body-thermal interaction during his PhD. After he became a member of the St. Anthony Falls Laboratory (SAFL), he has been conducting research on wind plants optimizations from an energetics perspective. His work has been well received and has made big impacts to the scientific community around the world. He has published 18 journal articles (11 articles as the first author) and 15 conference papers on numerical and experimental fluid mechanics. He was awarded the Best Dissertation Award by the Korean Society of Mechanical Engineers (KSME).

Dr. Lian Shen will also participate in this study. Dr. 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 (MIT) 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. He is currently serving on the national committee of ASCE Environmental & Water Resources Institute on CFD Applications in Water and Wastewater Treatment. Dr. Shen has organized many national and international conferences and symposiums.

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 21 faculty members and 37 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 measuring environmental flows at SAFL, which has 16,000 ft^2 of research space dedicated to physical modeling and experimentation. The facility, which has recently been upgraded with a $16M renovation, has 15 general purpose flumes, tanks, and channels readily configurable to the needs of projects. This project will utilize the SAFL wind tunnel, which is equipped with the ability to measure air temperature.

The proposed project will also use the Eolos wind energy research station, which is a premier research facility of SAFL. To help advance its goal of 20% wind power by 2030 in the United States, the Department of Energy awarded an $8 million grant to SAFL to build a wind research station containing a utility scale wind turbine and a 130 m meteorological tower in Rosemount, MN. The Clipper Liberty 2.5 MW turbine built is heavily instrumented in order to collect an immense amount of data and assist in research. The turbine began operating and collecting data in October 2011. This project will use the field measurement data of Eolos wind station.