Environment and Natural Resources Trust Fund
2015 Request for Proposals (RFP)

Project Title: **ENRTF ID:** 108-E

Assessing Environmental Impact of Wind Turbines in Minnesota

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

Total Project Budget: $ 528,000

Proposed Project Time Period for the Funding Requested: 3 years, July 2015 - June 2018

Summary:

Using cutting-edge experimental and computational tools, we will assess how the turbulent air flows induced by wind turbines affect bird migration, crop productivity and lake ecology in Minnesota

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Sponsoring Organization: U of MN

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Location

Region: Statewide

County Name: Statewide

City / Township:

Alternate Text for Visual:

flow measurements and computational simulation can quantify the air flows around wind farms to study their impact on bird migration, crop production and lake ecology.

_____ Funding Priorities _____ Multiple Benefits _____ Outcomes _____ Knowledge Base

_____ Extent of Impact _____ Innovation _____ Scientific/Tech Basis _____ Urgency

_____ Capacity Readiness _____ Leverage _______ TOTAL

PROJECT TITLE: Assessing Environmental Impact of Wind Turbines in Minnesota

I. PROJECT STATEMENT

Wind energy plays a major role in fulfilling Minnesota's recent commission to increase the state's Renewable Energy Standards (RES) to 40% by 2030 and to higher proportions thereafter (MN Laws 2013, Chapter 85 HF 729, Article 12, Section 4). Nowadays, the state-of-the-art wind farm spans hundreds of kilometers in scale with wind turbines towering above 100 m, imposing significant impact on the air flows in its neighborhood. This highly turbulent air flow can hamper migration of birds, but may enhance the moisture and heat exchange between crops and air to benefit agriculture productivity as reported by US News based on a recent research in Iowa. Moreover, the air flow induced by wind turbines near lakes can alter the re-aeration and vertical diffusion of lake oxygen, and impose further impact on lake ecology and aquatic habitats. Since Minnesota is widely covered by farmland, lakes and wild bird refuges, it is crucial and urgent for the state to determine the complex impact of wind energy on its environment and natural resources before vigorously pushing forward its ambitious clean energy goals.

The overall objective of the project is to assess the impact of wind turbines on agriculture productivity, lake ecology and bird migration in Minnesota using advanced engineering tools. We expect that the outcomes of the proposed research will: (1) provide scientific bases and impact assessment models for the state environmental agencies to better regulate wind farm siting and operations; (2) offer guidelines for renewable energy developers to optimize the location, turbine layout and operations of wind farms; (3) strengthen the interest and support from landowners for wind energy development.

To achieve our goal, we will conduct measurements and modeling analysis of air flows, heat and moisture transport around wind turbines and wind farms. The measured quantities will be incorporated into computer predictive models that evaluate their influence on bird migration, the crop productivity and lake ecology.

II. DESCRIPTION OF PROJECT ACTIVITIES

Activity 1: Field measurements around the 2.5 MW wind turbine Budget: $248,000

The measurements will be conducted around the 2.5 MW wind turbine research facility of St. Anthony Falls Laboratory of University of Minnesota, located in Rosemount, MN. We will measure the air flows induced by the wind turbine not only rely on conventional meteorological tower and wind profiling instruments, but also employ innovative flow tracers for quantifying the complex structures of air flows around a wind turbine as illustrated in Figure 1. The air flow measurements will be synchronized with the ground surface temperature mapping using infrared camera technology. The heat and moisture exchange will also be quantified using the temperature and humidity sensors near the ground around the turbine. As Figure 1 shows, these measurements can provide the necessary information to evaluate the impact of turbine on bird migration and crop growth in Activity 3.

Outcome	Completion Date
1. Field Measurements of the influence of wind turbine on surrounding air flows	3/30/2017
2. Measurements of turbine induced ground temperature variation, heat and moisture exchange rates and assessment of their correlation with air flows	12/31/2017
3. Measurements of turbine induced air flow, heat and moisture exchange rates under different turbine operational regimes and meteorological conditions	6/30/2018

Activity 2: Modeling effects of wind turbines on environments Budget: $150,000

In line with field measurements, we will use computer models to assess the induced air flows and heat and moisture exchange around wind turbines. The computer modeling study will complement field measurements through comparison and cross-validation. We will also use modeling to expand the database to a wide range of turbine operational regimes and meteorological conditions in the state. In addition, we will perform computer simulation of turbine impact on the re-aeration and vertical diffusion of lake oxygen, which is essential for lake ecology. Figure 2 illustrates how the information obtained from computer modelling can be used for assessing the wind farm impact on bird migration and oxygen re-aeration rate at lake areas.

Outcome	Completion Date
1. Computer assessment of the influence of wind turbines on surrounding air flows	6/30/2017
2. Computer assessment of the influence of turbines on heat and moisture exchange	6/30/2017
3. Computer assessment of the impact of turbines on oxygen re-aeration rate at lake area	12/31/2017

Activity 3: Analysis of environmental impacts of wind farms **Budget: $130,000**

We will use field measurement data and computer simulation to analyze the environmental impacts of wind farms. Through collaborations with state-wide environmental organizations and ecologists, we will develop user friendly predictive models for these state agencies to quickly assess the influence of wind turbine on bird migration, crop productivity and lake ecology. These models will take into account the information of farmland (distribution, size, landscape, crop types, etc.), bird migration (bird types, migration patterns) and Lakes (size, depth, etc.) that are specific for the state of Minnesota.

Outcome	Completion Date
1. User friendly models to assess the influence zone of wind farm on migration of birds, and guidelines for the wind farm developers to mitigate this negative impact	6/30/2018
2. User friendly models to assess wind farm impact on crop productivity	6/30/2018
3. User friendly models to assess wind farm impact on lake ecology and aquatic habitats based on the altered oxygen re-aeration rate at lake surfaces by the turbine	6/30/2018

III. PROJECT STRATEGY

A. Project Team/Partners

The research will be led by Prof. Jiarong Hong as project manager and the principal investigator (PI) for the experimental part of the project. Profs. Lian Shen and Fotis Sotiropoulos will serve as the co-PIs to lead the modeling and analysis efforts of the project. All the PIs are affiliated with St. Anthony Falls Laboratory of University of Minnesota. The PIs will be assisted by postdoctoral associate, graduate students, and staff engineer. Details are provided in the Project Manager Quantifications and Organization Description section.

B. Project Impact and Long-Term Strategy

The proposed project is expected to be completed in three years and have long yielding impact on the Minnesota renewable energy development. It will give the state a head start on shaping a scientifically sound wind energy policies and development regulations. The cutting-edge engineering tools employed in the project can provide valuable references for other environmental problems (e.g. watershed restoration, invasive mussel habitats, Asian carp migration). By demonstrating the benefit of wind turbine on crop productivity, our project could strengthen the cross fertilization of wind energy generation and local economies. Through offering effective strategies for mitigating potential negative impact of wind energy on bird migration and lake ecology, the proposed project can enhance awareness and appreciation of the Minnesotans on renewable energy.

C. Timeline Requirements

The proposed research requires three years to complete. In the first year, the research will mainly focus on developing the experimental and computational tools for quantifying air flows, temperature and moisture distributions around the turbine. The second year’s effort will be concentrated on extending our measurements and simulation to various turbine operational regimes and climate conditions. In the last year of the project, we will combine the results from both field measurements and computational simulation to develop easy-to-use assessment models for state environmental agencies and wind farm developers.

2015 Detailed Project Budget

Project Title: Assessing Environmental Impact of Wind Turbines in Minnesota

IV. TOTAL ENRTF REQUEST BUDGET [3 years]

BUDGET ITEM	AMOUNT
Personnel:	
Prof. Jiarong Hong, PI, at 6% time with 74.7% salary and 25.3% fringe benefits (3 years; 1 person)	$ 22,284
Prof. Lian Shen, co-PI, at 6% time with 74.7% salary and 25.3% fringe benefits (3 years; 1 person)	$ 24,906
Prof. Fotis Sotiropoulos, co-PI, at 3% time with 74.7% salary and 25.3% fringe benefits (3 years; 1 person)	$ 21,549
Post-doctoral Associate at 100% time with 82.3% salary and 17.7% fringe benefits (2 years; 1 person)	$ 120,174
Graduate Research Assistants at 50% time with 58.5% salary and 41.5% fringe benefits (3 years; 1.75 persons)	$ 230,747
Research Staff Engineer at 15% time with 79.1% salary and 20.9% fringe benefits (3 years; 1 person)	$ 59,580
Contracts: N/A	$ -
Equipment/Tools/Supplies: Equipment including two illumination light sources for flow visualization (2x$10,000); flow imaging system upgrade including calibration and alignment tools and GPS system ($10,000) the 3-year supplies for deployment (3x$6253).	$ 48,760
Acquisition (Fee Title or Permanent Easements): N/A	$ -
Travel: N/A	$ -
Additional Budget Items: N/A	$ -
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 528,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Other Non-State $ Being Applied to Project During Project Period: N/A	$ -	N/A
Other State $ Being Applied to Project During Project Period: N/A	$ -	N/A
In-kind Services During Project Period:	$ -	N/A
Unrecovered UMN Indirect costs (52% MTDC)	$ 202,371	*Secured*
Funding History: N/A	$ -	N/A

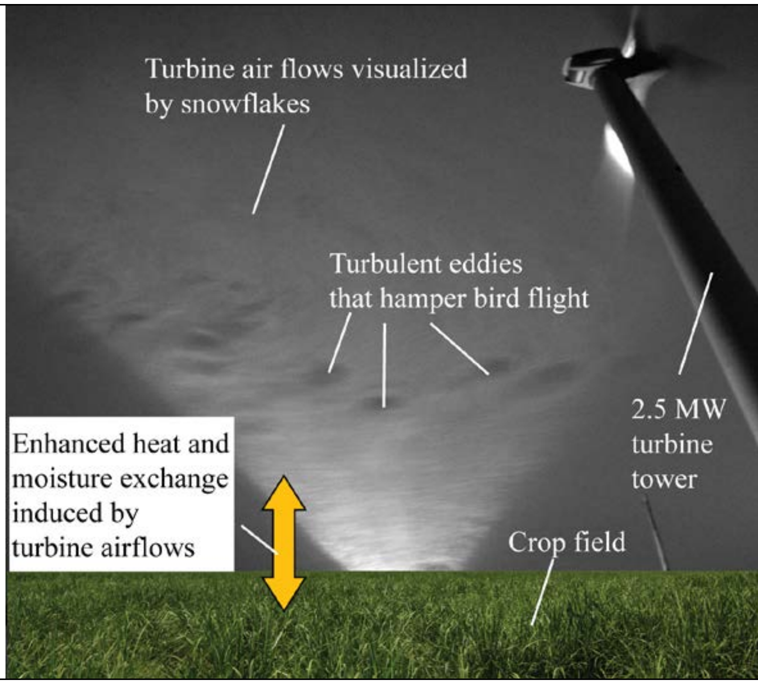

Figure 1. This visualization of air flows behind a 2.5 MW wind turbine can be used to determine its impact on crop productivity and bird migration. The visualization was performed using natural snowflakes as flow tracers. (*http://www.safl.umn.edu/featured-story/super-large-scale-flow-visualization-natural-snow*)

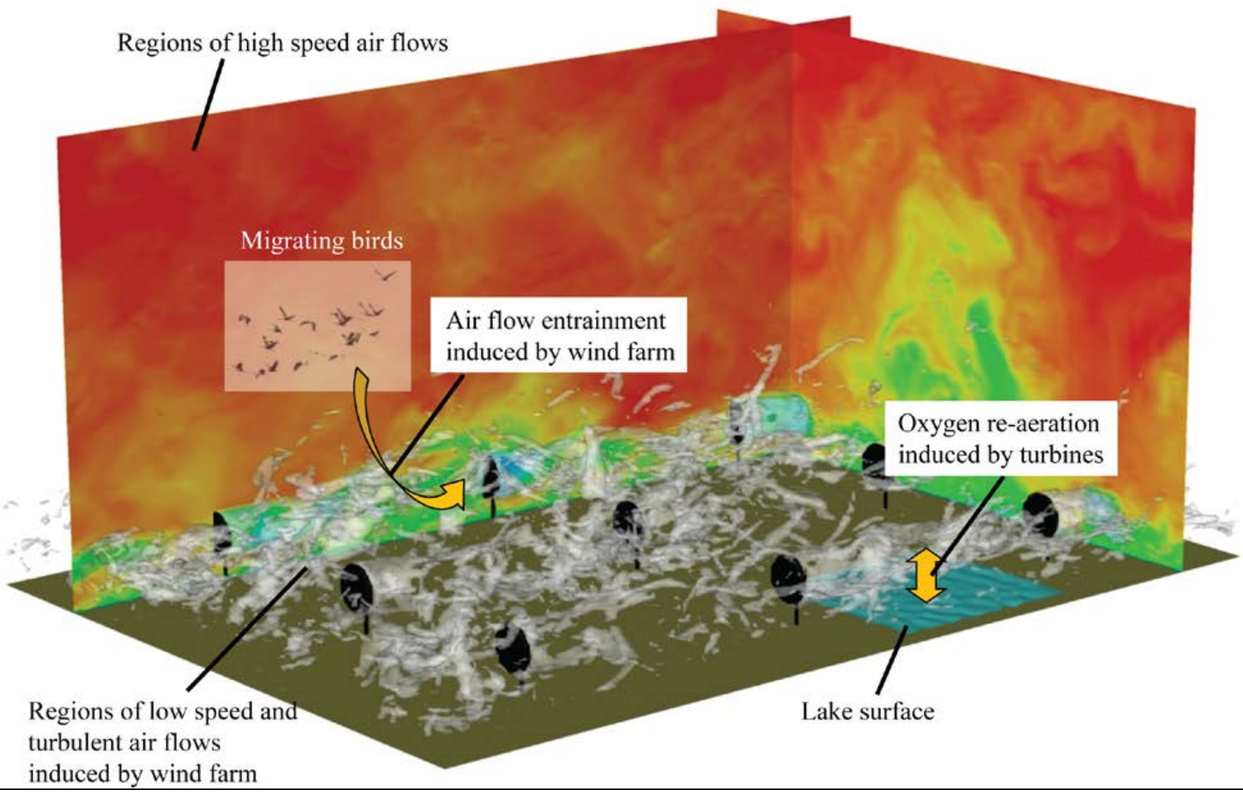

Figure 2. Computer simulated air flows induced by a wind farm can be used to determine its impact on migrating birds and re-aeration and vertical diffusion of lake oxygen.

Project Manager Quantifications and Organization Description

The proposed research will be performed in the St. Anthony Falls Laboratory (SAFL, http://www.safl.umn.edu) at University of Minnesota, Twin Cities. SAFL is a world-renown research laboratory in environmental and engineering fluid mechanics. The laboratory is affiliated with a number of departments within the College of Science and Engineering at the University of Minnesota. Recently, SAFL faculties have been integrating cutting-edge experimental work at laboratory and field scales with advanced computational tools and theory to obtain innovative, science-based solutions to renewable energy and environmental problems in real-world.

The research will be led by Prof. Jiarong Hong as project manager and the principal investigator (PI) for the experimental part of the project. Profs. Lian Shen and Fotis Sotiropoulos will serve as the co-PIs to lead the modeling and analysis efforts of the project. All the PIs are affiliated with SAFL. One postdoc and two graduate students and a research staff engineer will take part in the proposed project.

Prof. Jiarong Hong is the Benjamin Mayhugh Assistant Professor in SAFL and Department of Mechanical Engineering at University of Minnesota. He received his PhD from Johns Hopkins University in 2011 and joined University of Minnesota in 2012. His research at University of Minnesota is focused on understanding the airflows around industrial scale wind turbines using the innovative field measurement techniques.

Prof. Lian Shen currently holds the position of Benjamin Mayhugh Associate Professor in SAFL and Department of Mechanical Engineering at University of Minnesota. He obtained his PhD from Massachusetts Institute of Technology (MIT) in 2001. After three years of postdoctoral training at MIT, he joined the faculty at Johns Hopkins University (JHU). At JHU, Prof. Shen performed cutting-edge research on environmental air and water flows, transfer of greenhouse gases, and sustainable energy from wind and waves. He was recruited by University of Minnesota in 2012 to further strengthen the research on environmental flows and renewable energy.

Prof. Fotis Sotiropoulos is the director of SAFL and James L. Record Professor in Department of Civil Engineering at University of Minnesota. He received his PhD from University of Cincinnati in 1991. He joined the University of Minnesota as the director of SAFL in 2006. Prof. Sotiropoulos's research aims at developing high-resolution computational approaches for enabling virtual experiments and simulation-based engineering design in real-life environmental and renewable energy applications. His group's ongoing work focuses on wind/marine hydrokinetic turbines and farms; simulation of flows in natural aquatic environments, including coupled interactions of flow with biota; sediment transport and scour at bridge foundations and stream/river restoration structures.