Technical Review Form
GFO-16-310
EPIC Wind Energy Research Solicitation

Applicant Name:	Wind Harvest International (WHI)	**Proposal Number:**	07
Project Title:	Researching and developing the potential of Vertical Axis Wind Turbines (VAWTs) to double capacities of California's wind resource regions while preventing harm to birds – Phase I		
Reviewer Name:	Bruce Hamilton, Navigant Consulting Inc.		

Proposal Summary

Proposed Goals and Objectives:

The project goals are to:

- Reduce the costs and double the amount of wind energy in California;
- Determine if VAWTs harm birds, and if so, find ways to prevent this.

The stated objectives of the project are to complete the following tasks:

- Measure the wakes and turbulence produced by a pair of VAWTs and then a 4-turbine array and empirically show where Horizontal Axis Wind Turbines (HAWTs) should be placed in relation to VAWTs;
- Create a predictive methodology for Computational Fluid Dynamics - Large Eddy Simulation (CFD LES) modeling of VAWT-induced turbulence and wind speed that is validated against the field data;
- Determine optimal spacing of a downwind array of VAWTs from an upwind array;
- Provide data and modeling to universities and the wind industry so they can begin modeling how varying types of VAWTs and VAWT placement patterns in different topographies can best improve the capacity factor of HAWT wind farms;
- Determine how well DTBird motion detection and dissuasion technology can work with arrays of VAWTs;
- Evaluate how birds in the area of the VAWTs see and react to the VAWTs and whether any of species are harmed by the VAWTs; and
- Recommend strategies for research pilot projects in California on how to ensure that VAWTs don't harm wildlife.

Proposed Outcomes:

The project will collect wake and turbulence data that will validate the methodology and improve the accuracy of Stanford University's CFD LES model. VAWTs will reduce the cost of installed kW from the current $3,500/kW to less than half that cost in five years. In the long term, the project will lead to increased wind energy production in California, both by increasing the density of wind turbines by introducing VAWTs and by increasing the efficiency of existing HAWTs.

Key Innovation and Advantages:

The project will provide further evidence that VAWTs can be safely deployed in the understories of HAWTs and in fact will increase the average Capacity Factor of HAWTs by 1-2%. It will also show that VAWTs can achieve high efficiencies when they are placed close together in the "coupled vortex" position – counter-rotating, with one meter separating neighboring rotors. Finally, it will show that the DTBird motion detection system can accurately detect and record simulated bird flight patterns coming toward the VAWTs.

Strengths and Weaknesses per Scoring Criteria
1. Technical Merit and Need
Strengths: The scope of work (SOW) and Project Narrative clearly delineate specific project goals and objectives, which are consistent with California's goal of meeting its Renewable Portfolio Standard (RPS) requirements primarily with in-state resources. The narrative clearly states how the project will lead to increased wind energy production in California, both by increasing the density of wind turbines by introducing VAWTs and by increasing the efficiency of existing HAWTs. The project will confirm previous research (led by K. Wolfe, WHI COO and project manager) that VAWTs can achieve the efficiencies of modern HAWTs when they are placed close together in the "coupled vortex" position, counter-rotating. The project may also confirm the prediction that proper placement of VAWTs can increase the wind speeds reaching the HAWTs and their energy output.
Weaknesses: No major weaknesses noted.
2. Technical Approach
Strengths: The Project Narrative states that the following data will be collected and used in a Measurement and Verification Plan: • Wind speed and turbulence data from Doppler LIDAR and sonic anemometers; • Thermal and air density data; and • Video and in field mortality data on bird interactions with VAWTs. The project schedule calls for a 27+ month data collection period for detection of bird interactions with VAWT arrays at two different geographical locations. LIDAR and the DTBird motion detection system have both been used extensively in other research and they are appropriate for this application. The total project footprint as measured by the new foundations will be less than 50 square meters. No new roads will be needed. The only new fencing needed will be to protect the anemometer from cattle rubbing against its guy wires. There are no concerns expected of the neighbors in large part because of the half mile distance to the nearest neighbor. Based on these factors, the Applicant states that the County of Solano has indicated that a conditional use permit would be awarded with a mitigated negative declaration.
Weaknesses: Research on wind wakes and speed-up effects will not be done with HAWTs and their turbulence present. This is a known limitation of the project and will be specifically addressed in Phase II. It is not included in Phase I because wind farm owners will not allow their modern HAWTs to be part of a research project without some level of third-party validation of the impacts that VAWT arrays create for HAWTs.
3. Impacts and Benefits for California IOU Ratepayers
Strengths: There are two technologies that this research and development (R&D) project will help advance: WHI's G168 VAWTs and the placement patterns for VAWTs in general. The 70 kW G168 model

is claimed to be the most advanced VAWT in the industry; and, as part of this project, it will become the first VAWT larger than 5 kW that will achieve international certification.

This project will advance VAWTs by confirming the methodologies for predicting wake effects and avian mortality. It may also confirm the prediction that VAWTs in the understory, i.e. placed underneath, of HAWTs will be the least-expensive source of any energy option within five years and continue with that status throughout the full build-out of VAWT wind projects in the State. This research could open the door to 10,000 MW of new VAWT wind energy projects being developed in California by 2040. It will also result in benefits in lower costs, economic development, environmental benefits, public health, consumer appeal, and energy security.

Weaknesses:

No major weaknesses noted.

4. Team Qualifications, Capabilities, and Resources

Strengths:

The project will be developed by an experienced team with diverse skills essential to the successful demonstration of the VAWT technology. It will be led by Kevin Wolf, WHI's Chief Operating Officer, who has significant experience in managing complex tasks. Key tasks will be led by experts in their respective areas as follows:

- Professor Craig Clements and associate professor Neil Lareau of San Jose State University will serve as lead investigators on the project and will also oversee the LiDAR and sonic anemometer data collection and analysis;
- Dr. Sanjiva Lele of Stanford University will lead the CFD LES modeling;
- Two senior scientists from Garcia and Associates will conduct the bird related research;
- UL technicians will undertake measuring the effectiveness of the DTBird system.

By leveraging existing laboratories, research facilities, and established technologies, the applicants have created a cost-effective program to determine the value and environmental impacts of this nascent technology.

Weaknesses:

No major weaknesses noted.

5. Budget and Cost-Effectiveness

Strengths:

The $1.25 million budget request (net of matching funds) appears appropriate for the level of effort outlined in the SOW, technologies deployed, and personnel assigned to the project. The project makes good use of existing on-site LIDAR and anemometers and UL's Advanced Wind Turbine Testing Facility.

The Project Narrative makes the bold statement that VAWTs can be expected to achieve the same price per kWh as the most cost-effective HAWTs within 5-10 years. The Costs and Benefits Calculations document appropriately defends that statement, citing that Patriot Modular has quotes for an order of 100 units that reduces the current price by 25% and that additional decreases will occur due to learning curve effects.

Matching funds represent 23.9% of the total budget.

95.2% of funds (excluding matching funds) will be spent in California.

Weaknesses:

No major weaknesses noted.

6. Overall Strengths and Weaknesses and Reviewer's Recommendation

This project may lead to technological advancement and breakthroughs by proving that VAWT arrays, and WHI's G168 VAWT in particular, can safely be deployed in the understories of HAWTs in California's wind farms. This evidence may stimulate the HAWT industry to invest in VAWT engineering and development. The resulting increase in technical and manufacturing skills should lead to lower VAWT prices and lower energy costs for ratepayers. By applying existing skillsets and research techniques to VAWTs, the Applicant has created a cost effective and proven approach to demonstrating VAWT viability.

The proposal is strengthened by 6 Letters of Support including letters from all partner organizations.

There are no observed major weaknesses. Based on my review of the materials submitted by the Applicant, the reviewer believes it is reasonable for this grant to be funded.

7. Additional Comments:

- Omissions or missing material? None observed.
- Does this technology already occur? VAWT technology exists, but not when the VAWTs are placed close together or in the understory of HAWTs.
- Critical errors in approach. Will this technology work? No errors in the approach. LIDAR and the DTBird motion detection system have both been used extensively in other research but not in association with VAWTs.
- Errors in cost estimate: None observed. The costing appears to be compliant with the CEC's requirements.
- Issues with labor loading of the proposed Team: None. The labor loading appears to be reasonable.