Executive Summary Form

Researching and developing the potential of VAWTs to double capacities of California's wind farms while preventing harm to birds – Phase I

DRAFT – A proposal in response to the CEC EPIC Program's grant opportunity GFO-16-310 - *Improving Performance and Cost Effectiveness of Wind Energy Technologies*

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1. Project description:

California faces problems in increasing the share of wind energy in the state's electricity mix. It is difficult to add more Horizontal Axis Wind Turbines (HAWTs) to wind farms because of the negative impacts they create for each other when placed too close together. It is also increasingly expensive to permit, buy land, build roads and provide transmission lines for new wind farms. Further, large HAWTs pose threats to migratory and native bird populations, resulting in additional costs and difficulties in obtaining permits and developing environmental impact mitigation plans.

The use of Vertical Axis Wind Turbines (VAWTs) as a solution to these problems has not yet been investigated, due to lack utility scale VAWTS and data on their impacts to neighboring HAWTs and wildlife. Before wind farm owners will allow the large-scale deployment of VAWTs near HAWTs, field research must demonstrate that wakes produced by VAWTs have neutral or positive effects on the energy production and maintenance of nearby HAWTs. Before permits can be obtained for installation of VAWTs in most California wind farms, research must demonstrate that the turbines do not negatively impact bird populations.

In this project, WHI will conduct wind and wildlife research necessary to develop VAWTs as a commercially viable strategy for increasing energy production from existing and new wind farms

- Validate the modeling predictions of a 20% increase in energy output from pairs of VAWTs over single VAWTs.
- Produce the data needed to model how arras of closely spaced VAWTs affect wake and turbulence and whether the VAWTs could increase the wind speed that reaches the rotors of HAWTs.
- Use field monitoring in combination with motion detection monitoring to evaluate how birds and bats (if any) react to the VAWTs.
- Produce the information needed to conduct Phase II studies in CA wind farms.

If VAWTs can be safely deployed in the understories of HAWT arrays, this research will open up more than 5000 MWs of existing wind farms to make double use of the best wind resource lands in the state.

2. Project goals and objectives:

The goals of this project are to:

- reduce the costs of producing wind energy from existing and new wind projects by developing strategies of infill with VAWT arrays in the understories of HAWTs; and to
- conduct research necessary to prepare WHI's G168 model VAWT for pilot project operations in CA wind farms with sensitive bird species.

Project objectives are to:

- characterize the wakes produced by paired VAWTs in counter-rotating arrays on flat terrain;
- determine optimal spacing of G168 type VAWTs within a linear array to maximize the CF of the array and minimize problematic downwind turbulence;
- determine optimal spacing of a downwind array of VAWTs from an upwind array;
- provide data 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; and
- determine how well the DT Bird motion detection and dissuasion technology can work with arrays of VAWTs and recommend strategies for research pilot projects in CA on how to ensure VAWTs don't harm wildlife.

3. Explanation of how project goals and objectives will be achieved, quantified, and measured:

In this project, the team will deploy state-of-the-art direct and remotely sensing instrumentation to develop high-fidelity data and analyses of wind inflow to and wakes and wind speeds produced by VAWT arrays. Data from strain gauges, sonic anemometers and Doppler Lidar will allow for confirmation of the coupled vortex effect predicted by previous modeling and characterization of the speed-up effect predicted to occur above and downwind of the VAWT arrays. Data will used to calibrate CFD modeling done by Stanford University to predict turbulence in differing terrains. The Annual Energy Production and related predictions will be input into NREL's LCOE calculator to estimate the energy costs of VAWT – HAWT projects. The team will evaluate use of motion-activated cameras to supplement field data on any bird mortality caused by VAWT operation. Bird data will be analyzed and validated by a third party.

4. Project task description:

The work comprises 5 tasks. Tasks 1, 4, and 5 are mandatory general project management tasks. Tasks 2 & 3 are technical tasks. *Task 2 (Measurement of VAWT Wake Effects)* includes installation and calibration of meteorology towers equipped with sensor arrays, installation of a Doppler LIDAR unit, installation of a test array of VAWTs on rails to allow for repositioning of turbines, collection and analysis of data on inflow and wakes under varying wind conditions and array configurations, and dissemination of collected data through online databases. *Task 3 (Analysis of Bird Impacts)* includes installation and calibration of DT Bird detection and dissuasion systems on the test VAWTS, evaluation of the system's capabilities using drones, collection of bird mortality data using standard field collection techniques in conjunction with the system's motion-activated video cameras, and third party analysis of the collected data.

5. Agreement management description:

This research will be carried out in collaboration with independent certification company Underwriters Laboratory (UL); with researchers from the University of the Pacific (UOP) San Jose State University (SJSU); and Stanford University and with independent researchers in the fields of wind turbine aerodynamics (Neil Kelley) and wildlife biology (Garcia and Associates). The project team will work under the management of Wind Harvest International's Chief Operating Officer. Key personnel from WHI and the subcontractors will meet in person for an initial meeting at the research field site, and will conduct in-person technical meetings in conjunction with Critical Project Reviews. More frequent coordination will occur through Skype and other telecommunications platforms.