ATTACHMENT 4 - Project Narrative Form

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

1. Technical Merit and Need

1.a Overview and goals

California's Wind Resource Areas and regions are relatively small and few but have some of the best wind speeds in the country. Most of this land has already been built out or is being restricted from expansion because of wildlife concerns (Jawbone, Altamont), aviation height restrictions (Solano and Tehachapi/Mojave), or residents' concerns about their impact on views (San Gorgonio). Each wind farm and ridgeline is limited to a maximum number and megawatts of horizontal axis wind turbines (HAWTs) due to their susceptibility to near-ground and HAWT-induced turbulence.[1] Consequently, the state does not expect new onshore wind farms to supply a significant source of energy to meet its 2040 renewable energy goals, of which 90% must come from projects in the state or from those states directly connected to the state's grid.[2] New projects are facing higher land use costs because the supply is very limited.[3]

Figure 1. California has many ridgelines where VAWTs could be installed just downwind of the HAWTs and make double use of this high valued land.

The goal of this research and development project is to change that future to enable the state to, at minimum, *double the amount of low-cost wind energy produced from its most productive wind resources.*

The key to achieving this goal will be the commercialization of utility-scale vertical axis wind turbines (VAWTs) that can achieve the 20-year fatigue life needed for utility-scale wind farm operations in the highly turbulent near-ground winds that exist beneath HAWTs. The second part involves being able to operate VAWTs without creating harm to the HAWTs above and downwind nor to birds that inhabit or migrate through the area, especially endangered species.

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[1] "Wind Energy Explained. Theory, Design and Application" Manwell, J.F., McGowan, J.G. and Rogers,Al, John Wiley, U of Mass. Amherst, 2002

[2] "The California Wind Energy Association makes estimates of the current, near-term potential for further wind energy development. Taking into account current constraints on wind development in California, the association estimates that the near-term additional developable potential in the state is approximately 2,000 MW (Rader, 2016)." http://www.energy.ca.gov/2017publications/CEC-200-2017-001/CEC-200-2017-001.pdf

[3] "Estimated Cost of Ne Renewable and Fossil Generation in California", Draft Staff Report to the CEC, May 2014

The primary maintenance and repair related difference between VAWTs and HAWTs is that HAWT blades send the vibrations caused by turbulence in the wind to their drive train, causing harmful wear and tear to the bearings and gearbox. Near-ground wind is turbulent, a fundamental reason HAWTs are installed high above the ground[4]. A VAWT, with each of its blades attached to the rotor at two points, versus the single connection point of the HAWT blade, can withstand the near-ground turbulence.

Evidence from earlier CEC-funded research[5] demonstrated that VAWTs can achieve the efficiencies of modern HAWTs when they are placed close together in the "coupled vortex" position – counter-rotating, with one meter separating neighboring rotors. The drag and stall created by VAWT blades turning into the wind is countered by more wind being forced into each VAWT by its neighbor, resulting in the wind speeding up through their rotors, especially in the gap between the pair.

There are two major difference between VAWTs and HAWTs when it comes to birds. VAWT rotors are three dimensional while HAWT rotors are essentially two dimensional. Wildlife evolved in a three-dimensional world and should see and avoid VAWTs better than they can HAWTs. Also, their blade tip speeds are half as fast as the HAWT blades (150-200+ mph) operating in modern wind farms. WHI's G168 blade tip speeds range from 40 to a maximum of 90 mph.[6] The current thinking of many ornithologists is that, because of these factors, birds should able to see and avoid VAWT blades better than they do HAWTs.[7]

The primary scientific advancements this proposal helps achieve include:

- CFD- Large Eddy Simulation predictive modeling
- Understanding of bird eyesight of and behavior near moving objects
- LiDAR programming, data organizing and analytical tools
- Field measurements of DTBird motion detection capabilities

The primary technological innovations include:

- 140kW pairs of VAWTs maximizing the coupled vortex and porous wind fence effects
- Predictive modeling for how the placement of VAWT arrays can benefit HAWTs

1.b Overcoming barriers to achieve California's energy goals

Major barriers to increasing penetrations of wind power into California's electricity mix include:

- the difficulty of densifying energy production in existing wind farms,
- the high costs of greenfield wind farm projects in or out of state, and
- the lack of inexpensive to develop land with good wind resources and without aviation, endangered species or view-shed concerns.

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[4] "Wind Energy Explained. Theory, Design and Application"

[5] ""Modeling Blade Pitch and Solidities in Straight Bladed VAWTs". R. Thomas, K. Wolf , and Iopara Inc. EISG Grant #08-03, Final Report, 2011

[6] http://windharvest.com/g168-vawt/#description

[7] Personal conversations with many ornithologists and ecologists

If, as detailed in Benefit and Cost Calculation, this research confirms that VAWTs can be safely co-located among HAWTs, then 4-5000 MWs of VAWT capacity could conservatively be added to existing wind farms and adjacent wind resource lands by 2040. Another 4-5000 MWs[8] of VAWTs can be added in the high value[9] wind area north of the Hwy 12 and the Montezuma Hills. that is now off limits to turbines that have blades higher than 100 feet above the ground. VAWTs can easily stay beneath this height restriction.

Overcoming these barriers assumes that the success of this research project and the certification of Wind Harvest International's (WHI) G168 VAWTs will stimulate the major wind turbine manufacturers such as Vestas, GE, Siemens and others to start manufacturing VAWTs to compete in the enormous "near-ground" wind resource market that the research will help open. With these original equipment manufacturers entry into the market, prices of VAWTs should fall in the same way as they did for HAWTs. Within 5-10 years, VAWTs can be expected to achieve the same price per kWh as the most cost-effective HAWTs.[10] If, as predicted, proper placement of VAWTs can increase the wind speeds reaching the HAWTs and their energy output, then VAWT–HAWT projects will be even a less expensive energy option for California.

One of the other major barriers blocking the expansion of HAWT wind farms may also be overcome if the research from this project proves that VAWTs can be safely operated in habitats and migratory pathways of rare and endangered birds. It is unlikely that the bird related research as part of the grant application will eliminate all doubts that birds in the area won't fly into the VAWT rotors. It will help prove whether the DTBird system can be relied upon as it has been measured elsewhere[11] to capture bird events and trigger changes in the operation of the VAWTs in a timely manner. This research also will help overcome the problem of obtaining a permit for a larger VAWT project in bird sensitive areas.

All told, by overcoming the barriers blocking HAWT expansion in the state, research on VAWTs should stimulate another 10,000 MWs of wind energy in and adjacent to the state's Wind Resource Areas, primarily on land that has already been zoned for wind farms.

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[8] At least 100 square miles of land north of the Montezuma Hills and south of Dixon that have good to excellent wind resources according to the Solano County Wind Map. An array of eight G168 VAWTs would take up about 110 yards. If there was then a 90 yard gap before the next array, and this was a row one mile long, it would produce be 5 MW. With a conservative 80 yards as the projected distance between each row of VAWTs, there can be 22 rows in a mile. The total comes to >100 MWs per square mile. If all 100 square miles were built out then the capacity could reach 10,000 MWs in this, one of the state's best wind resources.

[9] "By wind resource area, Solano had the highest factor in July at 0.54 (and second highest average capacity factor in the state). The timing of Solano's highest capacity factor when compared to other areas brings it closer to the time of peak electricity sales." "It (Solano WRA's CF) peaked in July rather than June. In this way it matched electricity sales more closely than the other WRAs." http://www.energy.ca.gov/2017publications/CEC-200-2017-001/CEC-200-2017-001.pdf

[10] See Cost and Benefit Section

[11] "Evaluation of the DT Bird video-system at the Smola wind-power plant – Detection capabilities for capturing near-turbine avian behavior", Roel May, Oyvind Hamre, Roald Vang, and Torgeir Nygard, Norwegian Institute for Nature Research, NINA Report 910, 27pp, December 2012

1.c Status of current technology

There are two technologies that this R&D project will help advance – Wind Harvest International's G168 VAWTs in particular and placement patterns for VAWTs in general.

Figure 2 Graphic of VAWTs among HAWT rows north of Palm Springs CA

The core of the placement technology is well documented by a 2010 CEC grant that paid for the sophisticated modeling of the field data gained from an array of three smaller WHI prototype VAWTs that operated in North Palm Springs[12]. The modeling showed that low-solidity VAWTs like the new G168 would also realize WHI's patented "coupled vortex effect" and should produce about 20% more energy per turbine when placed in a pair than when operated separately.

In recent years, a growing body of field data and research, led in large part by Dr. John O Dabiri, has demonstrated how counter rotating VAWTs, when placed upwind of HAWTs throughout a wind farm, would bring higher, faster-moving wind down into the rotors of HAWTs.

> "For the vertical axis wind turbines, what you get, especially as you place them in close transverse proximity to each other, is that they can actually interact positively," Dr. Ann Craig said. "Although it is still an active area of research, we think that the VAWTs can have blockage effects causing speedup around the turbines that helps downstream turbines. They can also have vertical wind mixing in the turbine's wake region, which assists in the wind velocity recovery."[13]

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[12] http://windharvest.com/prototypes/#model-530g

[13] https://phys.org/news/2017-02-breakthrough-vertical-axis-turbines.html#jCp

Additional research has been done by leading VAWT modelers Drs. Ion and Marius Paraschiviou[14] that predicts a speed-up effect over the top of a tight VAWT array and would, if placed correctly, also increase the wind speeds realized by HAWTs immediately overhead.

WHI's VAWTs have gone through many prototype iterations, with the breakthrough coming recently with validation of an aeroelastic model using strain gauge data collected from the G168 prototype at the Nordic Folkecenter[15] in Denmark. Using the results from the validated model, a full Design Evaluation to IEC 61400-2 standards was turned into the U.S. Small Wind Certification Council[16]. Certification of the turbine should be completed in early 2018.

1.d. Need for EPIC Funding. A wind turbine company just venturing into commercial sales cannot afford to invest in this type of necessarily expensive research until sales are well established and profitable. In addition, this research is not adequately supported through competitive or regulated markets because the wind industry is disinclined to invest in VAWTs or consider allowing them to be placed upwind of their HAWTs if they might cause damage to their investments. Without some level of third-party validation of the impacts that VAWT arrays create for HAWTs, WHI has found it impossible to convince wind farm owners to allow their modern HAWTs to be part of a research project. The industry has little knowledge of VAWTs and is unlikely to pursue this technology without additional proof of its cost effectiveness, downwind effects, and impacts on wildlife.

1.e Technically Feasible and Achievable. This study deploys two technologies not previously applied to VAWT research: Doppler LIDAR and the DTBird motion detection system. Both have been used extensively in other research, and their use in this plan is technically feasible and achievable. Doppler LIDAR has been used extensively in wind farms and fire research to measure turbulence structures and changes in wind speeds similar to those predicted to be generated by WHI's VAWT arrays[17] . The LIDAR unit, when placed horizontally to the ground, can extract wind speed and turbulence data directly above and downwind of the VAWT arrays at the increments needed to model the speed-up effect and planform kinetic flux, and to predict whether downwind turbulence might rise into the rotors of HAWTs.

DTBird motion detection and avoidance systems have been used for over ten years in HAWT wind farms in Europe and have undergone independent evaluations of their effectiveness at detecting birds of various sizes at varying distances.[18] It is technically easy to adapt the system cameras to be placed around VAWT arrays.

The CFD - Large Eddy Simulation (LES) modeling that will be done by Dr. Sanjiva Lele and his postdoctoral students at Stanford University will build on the modeling he has done on HAWT

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[14] See Marius Paraschiviou's letter of support for the proposal
[15] http://windharvest.com/g168-vawt/#description
[16] http://smallwindcertification.org/applicant-turbines/
[17] Charland & Clements 2013
[18] "Evaluation of the DT Bird video-system at the Smola wind-power plant – Detection capabilities for capturing near-turbine avian behavior", Roel May, Oyvind Hamre, Roald Vang, and Torgeir Nygard, Norwegian Institute for Nature Research, NINA Report 910, 27pp, December 2012.

wakes and turbulence. Adapting this modeling to VAWTs has a high degree of feasibility and achievability.

The timeline for testing is achievable with almost an extra year of time available in the grant funding period incase if any delays develop.

1.f Evaluation of project benefits

. The following data will be collected and used in a Measurement and Verification Plan:

- Wind speed and turbulence data from LIDAR and sonic anemometers.
- Thermal and air density data
- Video and in field mortality data on bird interactions with VAWTs.

The data will be used to determine benefits and potential impacts from deployment of VAWT technology in California wind farms and of WHI's G168 VAWTs in particular.

- The "porous wind fence" speed up effect over the top of an array of VAWTs will be measured by the Doppler LiDAR. With this data, an empirically derived "map" can be made of the extent above the VAWT array that this speed up effect extends. The CFD model will also use this data to validate its predictions on how different changes to VAWT designs would affect the height to which the porous wind effect reaches. The analysis will then be evaluated against a USGS database of the different size and heights of HAWTs in the state to produce an estimate of the benefits the HAWTs could realize from this effect alone.

- The downstream vertical energy transport that is predicted to bring faster moving wind from higher altitudes down into the rotors of HAWTs will be measured with the sonic anemometers and LIDAR. This data will be used in the CFD model to validate the methodology that will allow for predictions for how different configurations of VAWTs can have the best impact on downwind HAWTs. This analysis will be evaluated against the USGS database of wind turbines in CA to create an estimate for the benefits to the state.

- The LiDAR and sonic anemometers will provide data for both an empirical and a modeling analysis of how far downwind and above the ground extends the turbulence that the pairs of VAWTs create. This data will help determine how closely a second row of VAWTs can be placed downwind of a first one. This information will then be used to evaluate the density that VAWTs can be placed in VAWT only projects such as would be allowed near George Air Force Base in the Mojave or Travis Air Force Base in Solano County where HAWTs are now restricted.

- 27 or more months of detection triggered, high fidelity video data will be collected on bird interactions with VAWT arrays at two different geographical locations. This data will help answer whether these types of turbines can be safely installed in territories or migratory paths of key bird species. If the VAWTs need to change operations and reduce energy output to avoid harming birds, this change in energy production will be used to modify the projected Levelized Cost of Energy (LCOE) of VAWT with HAWT and VAWT alone projects.

1.g CEQA compliance

This project will be located on the Emigh Land LP ranch in southern Solano County on land that will continue to be used for the grazing of cattle and sheep (Solano County APN 0048-010-030). 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. Except for the unknown about VAWT impacts to birds, Solano County would judge this project to meet CEQA with a Negative Declaration[19].

WHI is committed to protecting bird populations and individual special status species from being harmed by their product[20]. For this reason, WHI proposed to the county that the project should be permitted with a Mitigated Negative Declaration and a Conditional Use Permit. The mitigation requires changes to the turbines' operations (e.g. slowing of rotational RPM or if needed, a complete shutdown when birds of concern enter the DTBird detection zone). If avoidance techniques or changes in operations fail to protect key bird species, then the turbines will be required to be removed from the property.

In view of these facts, the county has indicated that they would approve the land use permit with Mitigated Negative Declaration under CEQA.

1. h Disadvantage Communities

This project is not in an area designated as a Disadvantaged Community.

1.j Project requirements: Maximizing the use of California's wind resources

This R&D project will develop technologies that increase the effective use and energy output of the most valuable wind resources in California. The project advances major reductions in the cost of operating existing projects, provides research critical to promote the installation of synergistic wind projects that use VAWTs with HAWTs, and helps develop WHI's modern small (70kW) VAWT that can open up wind energy distributed generation on properties where HAWTs would be prohibited. This project would also help as prove to HAWT manufacturers that they should also start making VAWTs and compete for its unique markets like the projected 10,000+ MWs of excellent and untapped near-ground wind resources in California.

If this grant application is funded, two to four or more 70kW G168 VAWTs will be installed as a net metering project in the PG&E service area just north of the Solano Wind Resource Area. They are expected to produce between 300,000 and 400,000 kWh per year per pair depending on the final wind speed. These turbines will be the first that WHI will have sold in California and will provide the company with an opportunity to showcase its turbines in the state.

Few places around the world have as much near ground wind resources as the passes of California. Along the tops of their hills and ridgelines, there is an acceleration effect that reduces or even eliminates the wind shear and makes the near ground wind resource as strong as it is at the higher hub heights of HAWTs. The least expensive way to increase the

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[19] Personal conversations with Jim Leland, Principal Planner, Department of Resource Management, Solano County - 707-784-6765

[20] http://windharvest.com/wildlife/#bird_impacts

percentage of wind in the states future renewable energy supplies would be to develop its most energetic near ground wind resources first.

The promise VAWTs hold for increasing the wind speeds that reach HAWT rotors make them tools that would increase capacity factors of HAWTs and thus help make these traditional turbines "the best in their respective classes".

WHI's VAWTs are made of steel and aluminum components with a small amount of fiberglass in some of its fairings. 99% by weight can be recycled at the end of its 20-40+ year useful life.

When VAWTs are used in capacity factor improvement projects, no additional transmission capacity[21] is provided to a wind farm but the wind farm's rotor swept area becomes significantly larger. Such projects are less costly and add more reliability to the electricity system because the wind farm can be predicted to produce more energy in lower wind speeds than it would without the addition of the VAWTs.

When used with HAWTs on new wind power sites or when added into existing projects, VAWTs help reduce the cost of energy, and improve the economic performance of the projects because they will:

- Make double use of the roads, fencing and other project infrastructure
- Double the energy output per acre of land
- Be placed in configurations that increase the wind speeds both types of turbines would otherwise realize.

2. Technical Approach

This proposal has three main technical areas of focus: 1) field data collection and analysis with Doppler LiDAR and a movable met mast. 2) CFD modeling and a validated methodology to predict the VAWT wake spreading and wake decay within an atmospheric boundary layer. 3) motion detection video analysis of bird interactions with VAWTs and associated field mortality studies. The approach, method and execution are discussed in the first three sections below

2.a Technique, Approach and Methods

Lidar and Sonic Anemometer Data and Analysis

The San Jose State University (SJSU) team, led by Prof. Craig Clements and Prof. Neil Lareau, will conduct the meteorological measurements component of the VAWT wake studies. These tasks include:

- installation and operation of meteorological instrumentation at the Solano wind resource area, including an atmospheric Doppler LiDAR and the California State University Mobile Atmospheric Profiling System (CSU-MAPS) equipped with a 32-m tower and five 3-D sonic anemometers.
- meteorological expertise to the overall project and experimental design

[21] "The cost of building new transmission lines ranges from $15 to $27 per megawatt-hour." - http://www.newsweek.com/whats-true-cost-wind-power-321480

- data analysis of the Doppler LiDAR data and turbulence data from the mobile tower. Data analyses will include:

  (1) quantification of vertical shear extent downstream of VAWT array;
  (2) characterization of atmospheric turbulence kinetic energy at multiple heights downstream of VAWT; and
  (3) characterization of VAWT wake structures during different atmospheric conditions.

Simulations of VAWT Wakes in Atmospheric Boundary Layers

Stanford University Prof. Sanjiva Lele and a post-doctoral student will validate computational simulations of the turbulent wakes of VAWT configurations in atmospheric turbulent boundary layers. They will leverage the experience in Dr. Lele's group on high-fidelity simulations of wind turbines, wind farms, and broader CFD applications involving turbulent flows. The computational model will be assessed and validated against field measurements obtained using Doppler LiDAR by the SJSU team. It is expected that a validated methodology to predict the VAWT wake spreading and decay within an atmospheric boundary layer will be available at the end of the proposed project.

The proposed computational model will be developed in four stages:
1) Aerodynamic modeling of VAWT wake for a single turbine (0-6 months)
2) Aerodynamic modeling of counter-rotating VAWT pair (0-6 months)
3) Simulations of VAWT pair wake in an atmospheric boundary layer (6-12 months)
4) Simulations of VAWT wakes for VAWT configurations (13-24 months)

The VAWT aerodynamic design parameters, such as the blade geometry, aspect ratios, tip speed, etc., and installation parameters such as the tower height, etc., will be chosen to correspond to the WHI G186 VAWTs used in the field tests. Additionally, the most important atmospheric boundary layer properties that influence the VAWTs' operation in the field site, such as the mean wind speed and mean vertical wind shear at mid-rotor plane, and turbulence intensity, will be matched as closely as possible with the field data in a plane upstream of the VAWT array. The predictions of the model will be compared against the field data in terms of quantifying the VAWT wake spreading and wake recovery and turbulence intensity as a function of downstream distance from the VAWT array.

The computational model aims to predict the evolution of VAWT wakes as they develop within a realistic turbulent atmospheric boundary layer, over downstream distances of the order of 10s of turbine rotor tip height. Additionally, it is of interest to capture the interactions amongst the wakes of multiple turbines, such as a pair of counter-rotating VAWTs, and multiple pairs of VAWTs within one array. In simulations which capture the flow behavior occurring over these extended spatial regions, say 300 m by 300 m, it is not feasible to simultaneously resolve the turbulent boundary layer over an individual turbine blade, their tip vortices, etc. Since it is the turbine wake evolution and its recovery within a realistic atmospheric boundary layer that is of primary interest in this project, the VAWT blades will be approximated with an actuator line model. Available aerodynamic performance data for the VAWT blades, such as the lift and drag coefficients as a function of the angle of attack, and Reynolds number (available through NASA and NREL documents) will be used in modeling the VAWT aerodynamics. Atmospheric turbulent boundary layers will be simulated using LES with a suitable wall model to prescribe the wall shear stress and wall heat flux (selected for the specific wind farm site in California).

An example of recent wind farm simulations conducted in Dr. Lele's group is included in Figure 3 as an illustration of the envisioned computations.

The proposed simulations represent the state of the art in wind turbine wake flow simulations. The model results will be systematically compared against available data. It is anticipated that measurements of the turbulent boundary layer approaching the VAWT array will be critical in ensuring that the computational model is correctly representing the effects of the atmospheric boundary layer turbulence. Comparisons at several downstream locations between the model predictions and measurements will serve as a test of model's accuracy in capturing the wake evolution and its decay.

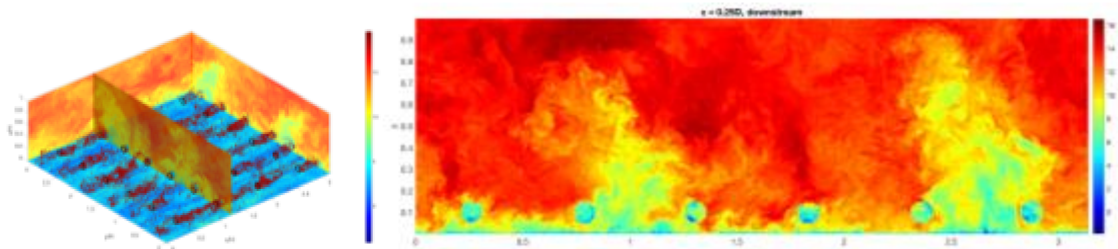

Figure 3: Simulation results from LES of a large wind farm with an array of HAWTs. A composite visualization of the turbulent boundary layer is shown in the left image. The right image is a slice of the flow field in a plane perpendicular to the mean wind. Note the large scale turbulent eddies and the turbulent wakes of six turbines, visible as distorted circular patches of low wind velocity. The data from this high resolution LES was used to evaluate the accuracy of the Kinematic Simulation method. It was found to successfully predict all second moment quantities accurately as well as the frequency and wavenumber spectrum of the wind velocity fluctuations at less than 1000 times the cost of full LES. Figure courtesy of Ghate A. S. & Lele, S. K. Refer to Ghate, A. S. and Lele, S. K. Subfilter Scale Enrichment of Wind Farm LES using Discrete Gabor-Fourier Modes, AIAA-2017-1164, AIAA SciTech Forum, 35th Wind Energy Symposium, Jan 9-13, 2017, Grapevine, TX for computational details.

Research on VAWT interactions with birds

The bird studies will start with the verification of the effectiveness of the DTBird system at UL's Advanced Wind Turbine Testing Facility in Texas, where a pair WHI G168 VAWT will be undergoing certification. UL staff will use drones to measure the responsiveness of DTBird's system to accurately detect and record simulated bird flight patterns coming toward the VAWTs. This data and analysis will provide an accurate assessment of how many bird interactions the system may miss.

The DTBird system will collect video data of the bird interactions with the VAWTs in Texas for one year. This video will be reviewed by the ornithologists with Garcia and Associates, a respected California environmental consulting firm. Someone on site in Texas will locate and preserve any bird that the video records as having been hit. Proper identification of the bird species will help validate what was seen on the video.

At the project site in California, another DTBird system will be installed. In addition to 15 months of video recording and analysis of detection events at this location, UC Davis interns trained by Garcia and Associates ornithologists will make weekly visits over 15 months to the Emigh

Ranch project site to conduct standardized carcass surveys in the vicinity of the VAWTs to determine the species and numbers of individuals potentially impacted by VAWTs. The mortality study will include carcass searches, as well as observer bias, scavenger removal and crippling studies. The resulting data will be analyzed in conjunction with relative abundance and densities of local species to quantify the effects of VAWTs on birds.

If birds are being harmed by the VAWTs, the team will employ and evaluate the dissuasion tools that come with the DTBird system. If these tools do not work, the team will program the VAWTs to reduce their RPMs from 66 to 10 and evaluate this. If the dramatic reduction in blade speed does not give birds the visual clues they need to avoid the blades, then the VAWTs will be programmed to come to a complete stop. If the VAWTs cannot be stopped in time to prevent harm to the birds, the VAWTs will be removed from the property as a condition of the Mitigated Negative Declaration.

As part of the project, Garcia and Associates will organize two Technical Advisory Committee meetings to gain outside insights and recommendations on how these studies can best be carried out in order to set up Phase II studies in wind farms and in other bird sensitive areas. If as expected, VAWTs are seen and avoided by birds at the Solano site, this does not mean that other bird species will react in the same way. More studies will be needed and the TAC will be made up of stakeholders who want to see the best science used in the proving of this hypothesis, or if the hypothesis does not hold, then in the best ways to protect birds from VAWT operations.

Outstanding Features

There are four outstanding features of this research:

1. the use of Doppler LIDAR and mobile met mast to characterize near-turbine wakes and have this expensive equipment be available for future wind energy related research
2. the use of state-of-the-art CFD LES to predict how VAWT wakes spread and decay
3. the use of DTBird's motion-activated cameras to collect bird strike data on VAWTs in conjunction with an on-site mortality study.
4. the use of the most advanced VAWT in the industry. WHI's G168 has submitted the Design Evaluation[22] of the G168 v1.1 VAWT to the U.S ICC-SWCC™ (Small Wind Certification Council). This 70kW VAWT will be the first VAWT larger than 5 kW that will achieve international certification.

2b. Task Execution and Coordination

The schedule and scope of work provide the basic time line for when tasks should start and be completed. Each team is responsible for their own work plans with the project manager providing the coordination between the different partners. In addition, the project manager, as Chief Operating Officer for WHI will be directly overseeing the VAWT project development, operations and maintenance. The project manager will also oversee WHI staff who work on the project.

2.c Critical factors, risks and barriers

Factors for success. Factors critical to the success of this plan include:

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Finding an excellent post-doctoral student to work with Dr. Lele at Stanford. This shouldn't be a problem because of the reputation of Dr. Lele and Stanford, and the uniqueness of the project.

Obtaining a good range of wind speeds of sufficient duration. This shouldn't be a problem because of the location of the project in one of the most consistently windy places in California, adjacent to the Solano Wind Resource Area.

Having many videos recorded or in person observations of bird interactions with VAWTs. The more interactions that occur, the better the resulting data set and confidence in the analysis.

<u>Risks.</u>

Insufficient LiDAR and Sonic Data is Collected. If for some reason the LiDAR unit becomes unusable for an extended period of time because of theft, damage or other factors, it is possible that insufficient data would be collected. As a backup plan, the second LiDAR that SJSU owns can be made available when it is not committed to other projects. It is also possible to rent a LiDAR unit, if the second unit owned by SJSU is unavailable. If something goes wrong with the portable met mast sensors, the SJSU team has backups including five extra sonic anemometers. In the schedule is an extra six months of time where additional data could be gathered and all the analysis could be completed before the end of 2020.

WHI is unable to provide turbines for the project. WHI plans to sell the turbine project in Solano county to investors who can make use of the available small wind turbine federal tax credits. If this doesn't happen, WHI will finance the project out of its capital. If it is short on capital, it will run a crowdfunding campaign to raise the capital for two turbines.

VAWTS Cause Unacceptable Harm to Birds. If the data show that birds fly into and are killed by the VAWTs and the DTBird dissuasion technology fails to prevent them from being near the turbines, then the DTBird capabilities to slow down and stop the VAWT turbines will be used. If the VAWTs cannot be operated without harming birds, then the turbines will be removed from the property.

Few if any bird interaction events are observed or recorded. If birds are not around or not recorded as flying near the VAWTs then the bird studies will be inconclusive.

<u>Barriers.</u> This project will help overcome three major barriers that prevent the large-scale deployment of VAWTs in California wind farms:

- concerns over their potential negative impact on HAWTs;
- difficulty obtaining VAWT research and pilot project permits in bird-sensitive areas due to their unknown and potentially negative impact on birds; and
- lack of a VAWT that can profitably be installed at wind farm scale.

<u>Limitations</u>. Research on wind wakes and speed-up effects will not be done with HAWTs and their turbulence present. The grant funds research done on land with the nearest HAWTs miles upwind. Analysis of the data cannot fully predict how HAWT wake interactions with VAWTs would create wakes and change downwind turbulence without doing additional tests in wind farms, which is why this proposal is Phase I and a critical step before Phase II research can begin within wind farms themselves. WHI fully expects to be able to expand on this initial research in California.

2.d Dissemination of knowledge

The data gained from the field research will go through a quality control process before being made available free to the public via a website hosted by WHI. An enormous amount of data will be collected that won't be used for the core modeling and analysis being done in this CEC research project. This data has value and can be used by others to extract out more information that will help better characterize and understand what happens to the wind as it passes over, around and through pairs of counter rotating VAWTs.

The LES model developed and run by Dr. Lele for this project is proprietary to the University but is made available to researchers without charge. Before the project is completed, the model configured to the shape and size to the G168 VAWT will be made available to other modelers and researchers. This will make it easier for universities and turbine manufacturers to evaluate the LiDAR data and modeling results on their own, and make it more likely that new modeling based insights will be derived from the data.

Each of the sub-contractors and WHI will present their parts of the findings of these studies to their respective national conferences. Presentations at annual AWEA conference will be most valuable into educating the wind industry about the results but all involved in the study will present the results of their work at their universities and other opportunities including before the CEC staff and stakeholders. Each of the subcontractors is expected to publish a peer-reviewed paper on the results. Papers, reports, data and other useful information from this project will be made available via WHI's web library.[23].

Please see Attachments 6 and 6a for the complete Scope of Work and Project Schedule.

2.e Scope of Work and Project Schedule

Please see Attachments 6 and 6a for the complete Scope of Work and Project Schedule.

2.f Stakeholder involvement and technology deployment

Separate from this CEC grant, WHI will organize a public workshop that will seek input from stakeholders in the Solano Wind Resource Area. Stakeholders include: the county, Travis Air Force Base, the Rio Vista and Solano County Chambers of Commerce, local and statewide environmental groups, the local wind industry, the local ranchers and farmers, radio tower and communication companies and the general public on the future of VAWTs in the region. This workshop will help stakeholders understand the options and provide feedback on how the project work can best advance to Phase II studies in the region.

Once funded for Phase I, WHI will be actively seeking funding to expand the Emigh Land LP project to a full MW of 14 VAWTs and continue research on the site. This will help with WHI sales, prices and margins. WHI will also pursue grants internationally to conduct Phase II studies in wind farms where different terrains, wind conditions, models of HAWTs and species of birds and bats are present. Presently WHI has an offer of support from Energy Unlimited for a Phase II project at one of its wind farms in the San Gorgonio Pass.[24] The San Gorgonio Pass

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[23] http://windharvest.com/library/

[24] See Harry Halloran's, Energy Unlimited Inc. Letter of Support

has the least number of bird issues in the state and would offers a large area of flat land where many rows of VAWTs could be installed as well as some of the most productive ridgelines.

To fully develop and validate the LES model's predictive abilities and bird and bat motion and acoustical detection and protection technologies, numerous future studies will need to be conducted. Until other VAWTs are available, each of these projects will need WHI's G168 VAWT. The more sales that occur through such R&D projects, the lower the manufacturing cost per turbine and the bigger its immediate market, which will primarily be to distributed projects where the energy price is much higher than it is for wind farms selling energy to IOUs. Before large scale projects start there the price per installed VAWT will need to drop.

3. Impacts and Benefits to California Ratepayers

3.a IOU Ratepayer Benefits.

This project holds promise to provide large amount of the lowest cost renewable energy of any of the other options. An analysis (see Cost and Benefits Calculations) of existing wind farms and wind resource areas shows that VAWT technology could more than double the capacity of the 5000+ MWs of existing wind farms in IOU service areas. VAWTs also could open up another 5000-10,000 MWs of wind farms on land currently restricted to short turbines like VAWTs in the Solano Wind Resource Area as well. Developing these resources will spare the state from needing to add more expensive much off-shore and out-of-state wind resources to its mix to meet its renewable energy goals.

VAWTs will *lower the LCOE* of wind power in CA since energy production can be substantially increased without many of the additional costs associated with greenfield projects (e.g. roads, fencing, land purchase, zoning). If VAWTs can increase the wind speeds and thus CFs realized by HAWT rotors as predicted, the benefits of VAWTs in existing and new wind farms will be further be increased and the LCOE of existing HAWTs will also drop.

3.b. Quantitative Estimates

. The following chart summarizes the Wind Resource Areas in the state and the estimates for future build out potential of each area. It assumes the following:

- On flat land, four times more capacity can be added with four rows of VAWTs per each row of HAWTs. Each row of VAWTs equals the capacity of the row of HAWTs.
- On ridges and hills, only one row of VAWTs can be added and thus these lands can only see a doubling of capacity.

Earlier in this narrative, in footnote 8, the conservative total of only 100 square miles of the wind land in southern Solano County is open to wind farms and the windy land only uses about half of its VAWT potential per acre to help protect wildlife and account for setback easements and other factors. At 5 MWs of VAWTs per mile long row and 22 rows per mile, each square mile would produce 100 MWs. Thus, another 10,000 MWs would be available for new VAWT wind farms. ***The total market potential for VAWTs would then exceed 20,000 MWs***

In addition, all the wind resource areas in California have good to excellent (15 - 18+ mph) near-ground (30-70' above ground level), average annual wind speeds in their passes and on their ridgelines and hill.[25] These wind speeds will produce 25-40% Capacity Factors for VAWTs that use the coupled vortex effect. If as expected, the VAWTs increase the output of existing HAWTs, the Capacity Factors for the original wind farm turbines will also increase.

If, as is projected in the Benefit-Costs Calculations section, VAWTs can achieve the price reductions that were achieved by HAWTs in their early years of development, then by 2025, LCOEs of $.05/kWh should be achieved by VAWT- HAWT projects while HAWT alone projects would be closer to and LOCE of $0.07/kWh. This would result in a substantial savings for IOU ratepayers

Wind Resource Area	Current MWs	% of MW in Flat Land	MWs of VAWTs on Flat Land	% of MW on Ridges	MWs of VAWTs on Ridges	Buildout Potential (MW)
Altamont	498	10%	199	90%	448	647
Eastern SD/Imperial	316	10%	126	90%	284	411
Kern County	3,292	25%	3,292	75%	2,469	5,761
San Gorgonio Pass	713	85%	2,424	15%	107	2,531
Solano Pass	1,032	20%	826	80%	826	1,651
Total	5,950	30%	7,140	70%	4,134	11,274

3.c. Applicability to CA Wind Resources

Wind energy in California can help balance the supply produced by photovoltaic energy sources. Wind energy in California's WRA most often continues to be produced into the night well after solar panels shut down. Large scale new wind farms in the state will exacerbate the afternoon spike in the supply curve but will provide help after sunset when demand is still high and fossil fuels would otherwise need to provide the supply.

Because most of CA Wind Resource Areas are in between major energy demand areas, they are well situated for expanded capacity and short distances to load areas. For example, the Solano Wind Resource Area is situated between the cities around the San Francisco Bay and in the Sacramento and Central Valleys. Production of energy in the state's WRA's would reduce the need to build new transmission lines to new wind farms to new out-of-state supplies.

Overall, this project could lead to a major new source of inexpensive wind energy in time to meet the State's goal of 50% of energy supplies from renewable sources.

3.d. Timeframe, Assumptions, and Calculations.

[25] WHI discussions with wind farm owners and wind industry reps.

The timeframe for which benefits are estimated is five years after the end of the research project (2025). Key assumptions in the prediction for when ratepayers will realize significant benefits from this project include:

- VAWTs will reduce in cost per installed kW from the $3500/kW now to less than half that price in five years, similar to how HAWT costs dropped over a similar length of time.[26]
- VAWTs will increase the average Capacity Factor (CF) of HAWTs by 1-2%.
- The costs of wind farm land and infrastructure development are 35% of total wind farm Capital Expenditure.[27] The costs to add an understory will be less than 20% of the costs of creating a "greenfield" wind farm.

We will use the NREL LCOE calculator to compare costs for a repowered San Gorgonio Pass wind farm with HAWTs only against costs of a HAWT and VAWT integrated wind farm. See Attachment 12.

3.e. Impacted Market Segments.

All wind farms in California could benefit from an understory of VAWTs if they don't harm birds.

3.f Qualitative Benefits to Ratepayers.

The ability to use short VAWTs to increase the CF and capacities of wind farms reduces pressure for new development in existing bird and bat habitat. If VAWTs can be economically operated to avoid bird and bat impacts, then new greenfield developments of VAWTs can be installed where proposed HAWT wind farms are controversial. This avoids problems with views, opening up of raw habitat, and reduces the pollution that would come from burning fossil fuels.

3.g. Cost-to-Benefit Analysis. – see Appendix 4

3.h. Technology Readiness Level. WHI's G168 VAWTs are ready to be ordered for this project. All design and prototype testing has been completed. As an R&D project with a very small footprint, Solano County indicates it would quickly be permitted with a Mitigated Negative Declaration and a Conditional Use Permit. The project is located in PG&E's territory.

4. Team Qualifications, Capabilities and Resources

4.a Organizational Structure

WHI's COO Kevin Wolf will oversee the project and manage all components of it. He is the most knowledgeable person in the company about the VAWT technology, manufacturing, patents, research and market potential. He is the lead inventor on WHI's most recent patent - "*Vertical and Geographical Placements of Arrays of Vertical-Axis Wind-Turbines (VAWTs)*," He has experience in construction project management, financing, permitting and related legal issues. He is well recognized for his experience in and ability to facilitate meetings of experts on diverse subjects (e.g. San Joaquin River Dissolved Oxygen TMDL, New Melones Dam Management Plan). Wolf's degree in Evolution and Ecology from UC Davis and his experience and background with environmental and ecological studies makes him well qualified to work with and manage the bird related studies.

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[26] 2011 Wind Technologies Market Report, US Department of Energy

[27] C. Monte, T. Stehly, B. Maples, E. Settle; 2014 Cost of Wind Energy Review, NREL

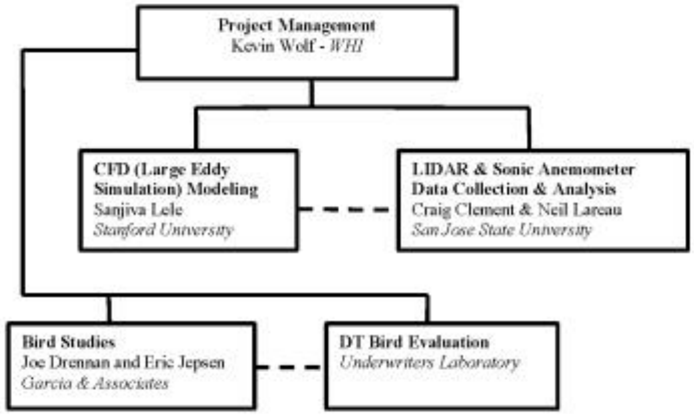

Figure 3 – WHI R&O Project Management

4. b&c Team members and qualifications

The technical content of this project will be divided into three areas: LiDAR and sonic anemometer data collection and analysis; CFD modeling; and impacts on birds. The lead investigators on the project will be professor Craig Clements with help from associate professor Neil Lareau of San Jose State University. They will also oversee the LiDAR and sonic anemometer data collection and analysis. The Stanford University team led by Dr. Sanjiva Lele will do the CFD LES modeling. Two senior scientists from Garcia and Associates will conduct the bird related research. The UL technicians will undertake measuring the effectiveness of the DTBird system. The project will be managed by Kevin Wolf, WHI's Chief Operating Officer

The qualifications and roles of team members who will provide leadership in their respective areas are summarized below, and resumes of key team members are provided in Attachment 5.

Professors Craig Clements and Neil Lareau are experts in the use of Doppler LiDAR and sonic anemometer data collection and analysis for complex meteorological phenomena such as forest fires. Dr. Clements uses LiDAR and mobile sonic met masts to characterize and measure vortices and turbulence related to fire events. Dr. Lareau worked at Lawrence Livermore National Laboratory using LiDAR to characterize the boundary-layer controls on the development of shallow cumulus clouds.

Professor Sanjiva Lele and his group at Stanford University have extensive experience in the use of high-fidelity simulations of wind turbines, wind farms, and broader CFD applications involving turbulent flows. They have developed highly accuracy numerical algorithms and CFD solvers for turbulent flow simulations for wind energy and environmental applications, and for aerospace technology applications. They also develop physics-based reduced order models using high-fidelity simulations and data from laboratory and field studies.

Joe Drennan and Eric Jepsen with San Francisco-based environmental consulting firm Garcia and Associates have extensive experience in conducting bird and wildlife studies throughout California. They have overseen extensive bird mortality studies in California wind farms.

4.d Task Management and Coordination

The project manager Kevin Wolf has experience in managing complex tasks. A Gantt chart with timelines and tasks that are updated every few weeks will be a key tool used in the project. Coordination will come from regular phone calls, in person meetings, good agendas and notes, all of which Wolf insignificant experience.

4.e Facilities and Resources

The DTBird system will be tested at the Advanced Wind Turbine Testing Facility in Texas where UL technicians are on staff who can accurately measure the system's ability to detect birds (drones) and the time it takes for that detection event to trigger a shutdown of the VAWTs.

The Texas site is also an excellent location to observe how non-endangered birds of prey and other birds interact with the VAWTs. Obtaining and analyzing a full four seasons worth of migratory and resident bird species will provide a significant boost in the data and analysis available. A year of data in a secondary site is better than an extra year of data at one site because of the increased richness of bird species and possible interactions.

The Emigh family ranch in Solano county is located in a major migratory and resident area for numerous birds including some listed as Rare or Endangered (i.e. Swainsons Hawk, Golden Eagles, Burrowing Owls). With cattle grazing right up to the foundation of the turbines, carcass searches as part of the mortality study will be more effective. The site is relatively close to UCD where the interns will come from who will be helping with the bird studies.

This ranch land is also in one of the windiest resources in California yet it is roughly three miles downwind of the nearest HAWT and well out of the shadow of their wakes. This ranch has plenty of land on which the mobile met mast can be placed and has an upwind topography that is near ideal for the data measurement and CFD modeling. The project can net meter into the PG&E transmission line that runs within meters of the project site.

The California State University Mobile Atmospheric Profiling System (CSU-MAPS) equipped with a 32m tower and five 3-d sonic anemometers will be made available for this research project. SJSU will purchase a second Halo Photonic Streamline Doppler LiDAR for use in this research. Their second unit can provide backup for certain times of the year if something goes wrong with the new LiDAR this grant will allow them to purchase. Drs. Clement and Lareau already have the algorithms developed that will allow for the organizing and analysis of the data.

Stanford University has the computing power needed for the computationally intensive modeling runs that validate the CFD against the field data. Dr. Lele has the basic complex CFD model needed for the simulations.

4.f History of project completion, references, support and commitments

Every member of the team has a history of successfully completing projects. All have received grant funding in the past and have accounted for the funds spent with successful projects. WHI does not have a history yet of bringing VAWTs into commercial sales but finally is at a point where it can.

4.g Past projects that resulted in market ready technology

None

4.h. References from relevant projects

See Attachment 9

4.j. Respond to the following questions

The answer to each of the following questions is “no”: (1) Has your organization been involved in a lawsuit or government investigation within the past five years? (3) Does your organization have overdue taxes? (2) Has your organization ever filed for or does it plan to file for bankruptcy? (4) Has any party that entered into an agreement with your organization terminated it? (5) For Energy Commission agreements listed in the application that were executed within the past five years, has your organization ever failed to provide a final report by the due date indicated in the agreement?

4.k. Commitment and Support Letters. WHI has secured letters of commitment from all project partners (Stanford University, San Jose State University, Garcia and Associates), the property owner Emigh Land LP and has provided its letter of commitment for match funds. In addition, letters of support are included from Energy Unlimited Inc wind farm owner Harry Halloran, stakeholder Emigh Land LP, and wind energy researcher Dr. Marius Paraschivoiu. See Attachment 11.

5. Budget and Cost Effectiveness

The project costs are outlined in Attachment 7 with the following total CEC funds being provide the main partners:

- $107,000 - Garcia and Associates
- $125,000 - Wind Harvest International
- $410,000 - Stanford University
- $471,000 - San Jose State University

The remaining costs will go to local, as yet to be determined, Solano County contractors, equipment, material and some travel. The breakdown by task area is show.

Table: WHI proposal budget summary.

5.a. Budget by Tasks

Task	CEC Funds	Match Share	Total
1 - Project Management	$62,490	$48,233	$110,723
2. Wake Measurement Analysis	$935,264	$192,000	$1,127,264
3 - Bird Impacts	$197,000	0	$197,000
5.1 - Evaluation of Project Benefits	$24,000	$23,000	$47,000
5.2 - Technology/Knowledge Transfer Activities	$31,245	$23,000	$54,245

ATTACHMENT 4 - Project Narrative Form

5.b Reasonableness of the Request

The potential of this project is enormous with the possibility that it triggers the development of $15 billion through 2040 in new VAWT wind farms in the state that otherwise would not have been built. The lower priced power these VAWTs would produce would save billions of dollars for IOU ratepayers through lower cost supplies of renewable energy.

In addition, this project makes use of existing equipment (e.g. SJSU portable met mast and work on LiDAR algorithms, Stanford's investment in LES modeling, WHI's VAWTs). The most expensive piece of equipment, the new Doppler LiDAR this project will pay for will be owned by SJSU and be available for future research that promises to help in future wind energy related research projects like WHI's proposed Phase II testing of VAWTs in wind farms themselves.

5.c. Reasonableness of cost of direct labor

WHI will cover all the fringe and indirect costs plus 30% of the direct labor costs that it anticipates putting into this project. This is a complex project involving numerous parts. The WHI team will also be doing the research and reporting needed to evaluate how much of an impact the resulting data and analysis would make in state wind farms and resource areas.

5.d. Reasonableness of personnel and subcontractor activities

University costs are standard and time spent by the professors is minimal compared to the lower costs time spent by masters and post-doctoral students. The wealth of experience brought to the table by the contractors will make their work efficient and effective per dollar spent.

5.e Maximizing funds for Technical Tasks

WHI is covering half of its direct labor related costs with matching funds. Less than 10% of the funds go to Direct Labor and less than half of those costs will be spent on administrative work

6. Funds Spent in California

With the purchase of the two DTBird Systems coming through the WHI office in CA and the sales tax on their sales going to the state, 98.3% of the budget is spent in CA. The only funds not spent in CA are the $18,000 in funds the go to UL for the drone work in TX, half of the funds for distance signs, and travel to TX for the associated work there. The out of state travel though will be from WHI's match funds.

7. Ratio of Direct Labor to Fringe Benefits

Using the formula given, the ration of Direct Labor and Fringe Benefits to load labor rates is 87%

8. Match Funding

The key factor in the match funding is the amount WHI anticipates having to pay the project investors above what they will receive from the energy sold to PG&E. The reasoning behind the amount of $2000 per turbine per months is explained in WHI's letter of commitment. This plus WHI's willingness to cover indirect and fringe and 30% of Direct Labor costs combines to $290,000 in match funding (23% of total).

9. Disadvantaged Communities

No impact until VAWTs are built in wind farms in disadvantaged communities but the project in Solano County is not in such a community.