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"EPIC Interim Investment Plan - *Validating near-ground wind speeds in existing wind farms and California's wind resource areas and improving LCOEs*

Wind Harvest, a California-based company, encourages the CEC to use EPIC 2021-22 funds to do the following:

- Evaluate old wind speed data and other resources to determine the value of the near-ground layer of wind below 100 feet that blows through the state's Wind Resource Areas. Our studies show that over 15,000 MWs of capacity could be added to these areas if much shorter turbines were available for purchase.
- Work with NREL and the renewable energy industry to produce Levelized Cost of Energy calculations and give the utilities, the industry and state decision makers a key tool they need to plan to plan and support the lowest cost, 100% renewable energy sources and produce the most positives for ratepayers, disadvantaged communities, wildlife habitat and local economies as possible.

The CEC's 1985 Wind Atlas analyzed data collected at 30-40 feet above the ground across the state. It showed that in many locations, near and high above ground winds were strong, and wind shears were low. By 2012, the resource areas were built out to capacity using large propeller-type turbines' existing technology. Given the wake and turbulence problems that more tightly spaced tall turbines would cause for their neighbors, no additional capacity is expected to be added in these highly windy areas.

In 2011, the CEC funded Wind Harvest to hire Iopara Inc. to model the Coupled Vortex Effect. The resulting computer modeling of the what happens when H-type vertical axis wind turbine blades pass within a few feet of each other validated that the CVE would result in a 15-20% increase in each turbine's energy output. Wind Harvester type turbines could now achieve the high efficiencies and Capacity Factors of modern horizontal axis turbines. The question remains whether H-type turbines can be made durable enough to handle the intense turbulence and gusts that accompany the near-ground wind layer in California's wind farms.

In 2017, three grant applications were made to EPIC to help VAWT technology become ready to meet the many different market niches where large HAWTs cannot secure permits. Unfortunately, in her review of these applications, Jocelyn Brown-Saracino, the Program Manager of Market Acceleration & Deployment for the (U.S) Wind Energy Technologies Office recommended that the CEC not award grants to these applications "*due to technical challenges associated with their (VAWT) performance (energy production on average lower than predicted) and also due to issues associated with reliability and maintenance*.

We are in the process of solving that Catch-22 with our crowdfunding campaign. In December we ordered v3.1 to complete Technology Readiness Level 7 at the UL Advanced Wind Turbine Testing Facility in Texas this spring. In October, our fully commercial v3.2 will enter IEC 61400-2 certification at the same facility. When this process is completed, we will have met the hurtle that Ms. Brown-Saracino identified.

We hope that the second problem she raised can be addressed with a small amount of funding from the CEC this coming year.

"The proposal(s) suggests that VAWTs might be used as an understory below HAWTs and suggests that the primary driver for the height of HAWTs is that near-ground wind is too turbulent. Wind resource is much greater at height and this calls into question the resource potential for VAWTs deployed in this fashion".

Her viewpoint was understandable given the history of VAWTs and that she had never read the CEC' Wind Atlas (nor the Coupled Vortex research paper). Nor had anyone else in the CEC granting panel. It had been over 30+ years since the Atlas was published.

In response to learning that information about the state's excellent near-ground wind resources had been forgotten, Wind Harvest received the CEC's permission to publish excerpts of their 1985 Wind Atlas. However, it is clear that more needs to be done to prove that near-ground wind resources are as extensive and strong as our new analysis indicates.

With permission from UL, we have started to publish Windnavigator (formerly AWS Truewind) estimates of near-ground wind speeds in wind farms around the world. Our report extrapolated the UL data to estimate that 20% of today's wind farms with over 100,000 MWs of capacity have wind speeds exceeding 6.5m/s (14.5 mph) at 20m above ground level.

We are working on producing rough maps of the 20m above ground level wind resources in all of the state's wind farms and adjacent windy properties. For the evaluation of the San Gorgonio Pass, we hired meteorologist Rich Simon (who helped the CEC with their late 1970s and early 1980 field data that was used to make the 1985 Wind Atlas). Rich provided average annual wind speeds from 50-60m met towers with multiple levels of measurement so that the 20m wind could be interpolated. We used that to see how accurate Windnavigator was. In the windiest section, Windnavigator underestimated the wind speed by 0.1m/s. In the other areas, UL's model overestimated the wind speed by 0.59m/s. We adjusted the SGP data to account for that but have left the other estimated wind speeds as provided by UL.

	Existing		**Wind Harvester Potential**	
	MW	**MWh**	**MW**	**MWh**
San Diego County WRA	439	1,309,773	909	2,553,312
San Gorgonio Pass WRA*	596	2,644,804	3,652	11,310,597
Solano WRA	1,072	3,780,206	4,149	11,148,398
Tehachapi WRA	1,713	6,910,541	7,827	25,197,294
Totals	**3,820**	**14,645,324**	**16,755**	**50,810,281**

Still to be mapped are the near-ground wind resources the Altamont Pass, Hatchet Ridge, Jawbone Canyon, Lompoc, and the Pacheco Pass.

We propose that the CEC hire meteorologists such as Rich Simon who have near-ground wind speed data in these areas that can be used to validate the UL analysis in more detail and accuracy than we can afford to do. A report could be quickly completed because no additional field data should be needed to confirm our maps. The maps would help wind industry and property owners value near-ground wind resources. Ideally a positive report would be used to support CEC and DOE grant funding in 2023 and beyond to help the manufacturers and developers of near-ground wind turbines and projects conduct the following research that will be needed before the full potential of near-ground wind resources can be used for the benefit of utility ratepayers.

1. How can the placement of tightly spaced H-type turbines benefit the tall HAWTs by bringing faster moving wind into their rotors? Research from Stanford and CalTech indicates that understories of Wind Harvester-type turbines can increase the tall turbines' annual energy production by 10% or more.
2. How can dense installations of H-type turbines be installed and operated so they don't harm wildlife, especially birds of prey like condors, golden eagles and Swainson hawks? The best current but untested hypothesis is that birds will see these three-dimensional turbines and avoid them.
3. How much can capacity factors (CF) of existing wind farms be increased without adding a second transmission line to the property? Most wind farms in the state have 25-40% CFs. We think that with batteries, these wind farms could exceed 80% CFs and extend the life of the existing wind turbine fleet by 5-10+ years. Is this true?
4. How can the state support local manufacturing and assembly facilities to build out the 15,000+ MWs of near-ground turbine potential? More than $20 billion in product would be needed to meet this market demand over the next decade.
5. How can the state support a rapid build-out of these resources, especially if they would provide the least expensive alternative to ratepayers? For example, Wind Harvesters can last 40-60+ years with regular replacements of bearings and power converters because they are made of aluminum, galvanized steel, and have permanent magnet generators. If capital markets could monetize this longevity, the price of the energy they produced would drop dramatically.

Lastly, we want to address the potential that these near-ground wind resources will benefit state ratepayers. Using existing Levelized Cost of Energy Analyses to compare different renewable energy options for the decade to come is rife with problems. For example, if our turbines could be valued in an LCOE with a 40-year life instead of a 20-year life, the price of energy produced would drop by over 30%. If the cost of capital (fixed charge rate) was reduced from 8% to 4%, the LCOE drops almost in half. If value was placed on when during the day the energy was produced, the significant amount of energy wind turbines produce at night without batteries would result in a lower LCOE compared to battery discharged renewable energy. We encourage the CEC to allocate 2021-22 funds to work with NRE, the DOE and the wind industry to produce a more sophisticated LCOE analysis of the energy options available to the state in the coming years. Here is our simplified analysis indicating why near-ground wind could be the least expensive energy available to utilities and ratepayers. Note that all tax credits, depreciation benefits and other subsidies have been removed from the analysis to create a better "apples-to-apples" comparison of these alternatives. You can plug the numbers in the table below to produce the same LCOEs in the bottom rows.

$$\mathrm{LCOE} = \frac{(\mathrm{CapEx} \times \mathrm{FCR}) + \mathrm{OpEx}}{(\mathrm{AEP_{net}}/1{,}000)}$$

100 MW Projects	National Wind Farm	CA Wind Farm	Wind Harvester Understory	Wind Harvester Raw Land	Wind Harvester Understory	Solar Farm CA
Life expectancy (years)	20	20	20	40	40	20
Turbine or Panel /support	$1,244	$1,244	$1,550	$1,915	$1,915	$750
Balance of System (roads, grid)	$360	$860	$150	$500	$150	$400
Financial Costs	$144	$189	$186	$217	$186	$104
CapEx	$1,748	$2,293	$1,886	$2,632	$2,251	$1,254
Operation exp. ($/kW/yr)	$44	$44	$30	$60	$60	$5
Fixed charge rate (FCR %)	8%	8%	8%	8%	8%	8%
Net annual Energy (MWh/MW/yr)	3,633	3,400	2,800	2,800	2,800	1,978
Net Capacity Factor	41.5%	38.8%	32.0%	32.0%	32.0%	22.6%
Total LCOE - 8% FCR	$0.051	$0.067	$0.065	$0.048	$0.043	$0.053
Total LCOE - 4% FCR	$0.031	$0.040	$0.038	$0.030	$0.027	$0.028

Thank you for considering these comments and recommendations. We are happy to answer any questions and provide you with as much information as we have.

Best regards,

Kevin Wolf, CEO
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