Repower California wind farms by adding layers of turbines without causing harm to wildlife
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The relatively small areas in California with excellent wind resources, and the limits on placing more horizontal axis wind turbines (HAWTs) in them justify both the use of EPIC funds to evaluate how valuable the state's near-ground wind resources could become and the investment in R&D needed for their development and build out.

Background

In order to optimize their near-ground wind resources, California wind farm owners need cost-effective wind turbines that operate efficiently in high turbulence and that do so without the wake from the added turbines negatively impacting the existing HAWTs.

The good-to-excellent average annual wind speeds (6-9 m/s, 14–20 mph) found at 10–25m above ground level in California's wind farms are well known to wind farm owners and developers. Experts* widely acknowledge that the wind moving through California passes or over its ridgelines accelerates, with wind shears decreasing dramatically in these topographies. Meteorological data also show that there is thermal and obstacle-induced turbulence in the high-energy, near-ground wind found in four of the state's five Wind Resource Areas.

In the last EPIC Wind Energy solicitation, GFO-16-310, three applicants associated with CA universities and businesses requested funding to advance R&D on vertical axis wind turbine (VAWT) technology and wake modeling. All their proposals failed to make minimum qualifying scores.

Near-Ground Turbulence

HAWT gearboxes and bearings have more repair problems when their blades pass through turbulence. This is one reason why they are set so far apart from one another in wind farms and why the bottom sweep of their blades is set to stay above near-ground turbulent winds. As a result, their rows are hundreds of meters downwind of each other, and the bottom tips of HAWT blades are between 20 and 50m above ground level. This leaves a lot of high-value wind resource unused by traditional wind turbines.

VAWTs are able to withstand highly turbulent wind primarily because their blades are attached to the rotating shaft at two or more locations, and they don't have to yaw into the wind. HAWT problems with turbulence primarily arise from their long blades connecting to the drive shaft at only one end and their large rotor having to operate in changing wind speed and direction. The blades and bearings used in these HAWTs would have to be substantially strengthened to withstand the high peak and cyclic loads from the near-ground layer of extreme turbulence.

The good news is that at least one such wind turbine (i.e., WHI's G168 VAWTs) is ready for certification and operation underneath HAWTs. Other turbines could also be commercialized and do well in the turbulent lower layers of wind farms (e.g., Stanford/Dabiri's VAWTs) once their engineers and investors are confident of their aeroelastic modeling and prototypes.

Why VAWTs Now

Historically, VAWTs have had trouble with their mechanical designs and durability because they lacked the field-validated aeroelastic modeling that HAWT engineers have. That issue has recently been resolved by WHI and the Technical University of Denmark - DTU.

The latest in aerodynamic modeling funded by a 2010 CEC EISG grant to WHI proved that G168-type VAWTs would also experience the "coupled vortex effect" and create 20–30% more energy production from a pair of closely spaced rotors than from two single VAWTs operating further apart. This solved the long-standing problem VAWTs faced: specifically, that the drag their blades created as they returned into the wind would prevent them from realizing much more than a 40% efficiency, whereas HAWTs can achieve 50% efficiencies. With the coupled vortex effect, counter-rotating VAWTs placed a meter apart from each other can be competitive with HAWTs.

Because arrays of VAWTs block some of the wind, a speed-up effect occurs over and around them similar to how it moves over a hill or ridgeline. In theory, VAWTs can be positioned so that the changes in air pressure, vertical mixing and wind speeds they create are channeled to increase the energy output of the taller HAWTs, and vice versa.

EPIC Program

Given the enormous untapped potential in California's existing wind farms, EPIC funds would be well invested in helping commercialize new types of wind turbines designed to harvest different wind layers and increase wind speeds at HAWT hub-heights. Other than WHI's EISG grant, little of DOE or CEC funding has been spent on VAWT research in decades. Funding for R&D that helps develop technology that can harvest near-ground wind is needed at all stages of the products' commercialization. There are a number of barriers that have prevented VAWTs from receiving EPIC funds. Given modern VAWT's potential and our world's need for clean energy, *it is time to remove those barriers.*

In the most recent EPIC Wind Energy (GFO-16-310) solicitation, RCAM Technologies won $1.25 million to "develop and test a reinforced concrete additive manufacturing (RCAM) technology for building low-cost, ultra-tall (140m) wind turbine towers on-site at the wind plant." On a 140m tower, the bottom of a 3-4 MW HAWT blade would be 80-100m above the ground.

With such tall HAWTs, it's conceivable to have four layers of wind turbines synergistically nesting above and around each other. For example, Dabiri's 9m-tall VAWTs could be upwind of WHI's G168 VAWTs installed on 10-20m towers in an array aligned perpendicular to the prevailing wind. These larger VAWTs could be placed 10-30vmeters upwind or downwind of a 1

MW HAWT on a 50m tower. Between the 50m HAWTs could be a row of 140m ultra-tall wind turbines.

A key barrier preventing EPIC from funding science and engineering of new turbine placement paradigms is the restriction: *"Projects focused mainly on siting or optimally locating wind turbines, including wind pattern modeling, are outside of this solicitation."* WHI's proposal would have used San Jose State University LiDAR to collect data and Stanford professor Sanjiva Lele's lab to model how VAWT arrays can create the "porous wind fence effect" and whether their wakes might harm HAWTs. This proposed research was interpreted as being in the same R&D category as investing in the well-established modeling of HAWT placement in wind farms.

Future EPIC wind energy solicitations should welcome proposals that seek to double the energy output of existing wind farms, and remove the barriers that prevent those proposals from scoring well.

Wildlife

VAWTs will eventually enter the wind farm market. When they do, enough information will be known about their impacts on wildlife so that their large-scale installations can be properly evaluated through the California Environmental Quality Act (CEQA) process. Both Dabiri's and WHI's most recent EPIC proposals included new ways of documenting how birds and bats react to VAWTs. Biologists theorize that these animals evolved to fly around three-dimensional objects, such as trees and VAWTs, and will have an easier time avoiding their blades than they do those of two-dimensional HAWTs.

Producing field data on VAWTs' potential impacts to birds and other species is a fundamental first step. Given their potential to be safely installed in valuable wind resource lands in endangered species' habitat, the EPIC review process should give credit to applications that also advance scientific knowledge on VAWTs and wildlife.

Benefits to Ratepayers

Installing thousands of megawatts of new capacity in the state's wind farms promises to help ratepayers and California manufacturing to a greater degree than would building new transmission lines and wind farms in Wyoming or off the California coast. Layering VAWTs among HAWTs is predicted to have a lower LCOE than almost any other option, especially as time-of-day production becomes more valued in the utilities' pricing structure. New capacity in the state's Wind Resource Areas would turn wind into electrical energy well into the night, long after photovoltaics stop producing energy.

According to Project Drawdown, the second best way to meet carbon reduction goals is with on-shore wind development. Making double use of existing wind farm infrastructure to harvest the lower wind layers of some of the best wind resources in the country that are uniquely close to the state's largest electrical markets *should be a priority on the state's road map for achieving its carbon and pollution reduction goals while keeping ratepayer costs low*.

* The following wind industry meteorologists and experts will confirm that there are good to excellent near-ground wind resources in California's Wind Resource Areas. Note that titles and associated organizations are used for identification purposes only:

Allen Becker, consulting meteorologist, Forensic Meteorological Consulting
John Bosche, President and Principal Engineer at ArcVera Renewables
Neil Kelley, Applied Meteorologist, retired
Pep Moreno, CEO Vortex
Ron Nierenberg, consulting meteorologist
Lucille Olszewski, General Manager, Ensemble Wind
Richard Simon, Wind Industry Meteorologist
John Wade, Senior Meteorologist, Ensemble Wind
ArcVera Renewables, wind prospecting and resource assessment
WindSim, CFD Wind Resource Assessment