*Supplement of*

# Locating the Optimal Wind Resource within two Californian Offshore Wind Energy Areas

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# S1 Power Curve

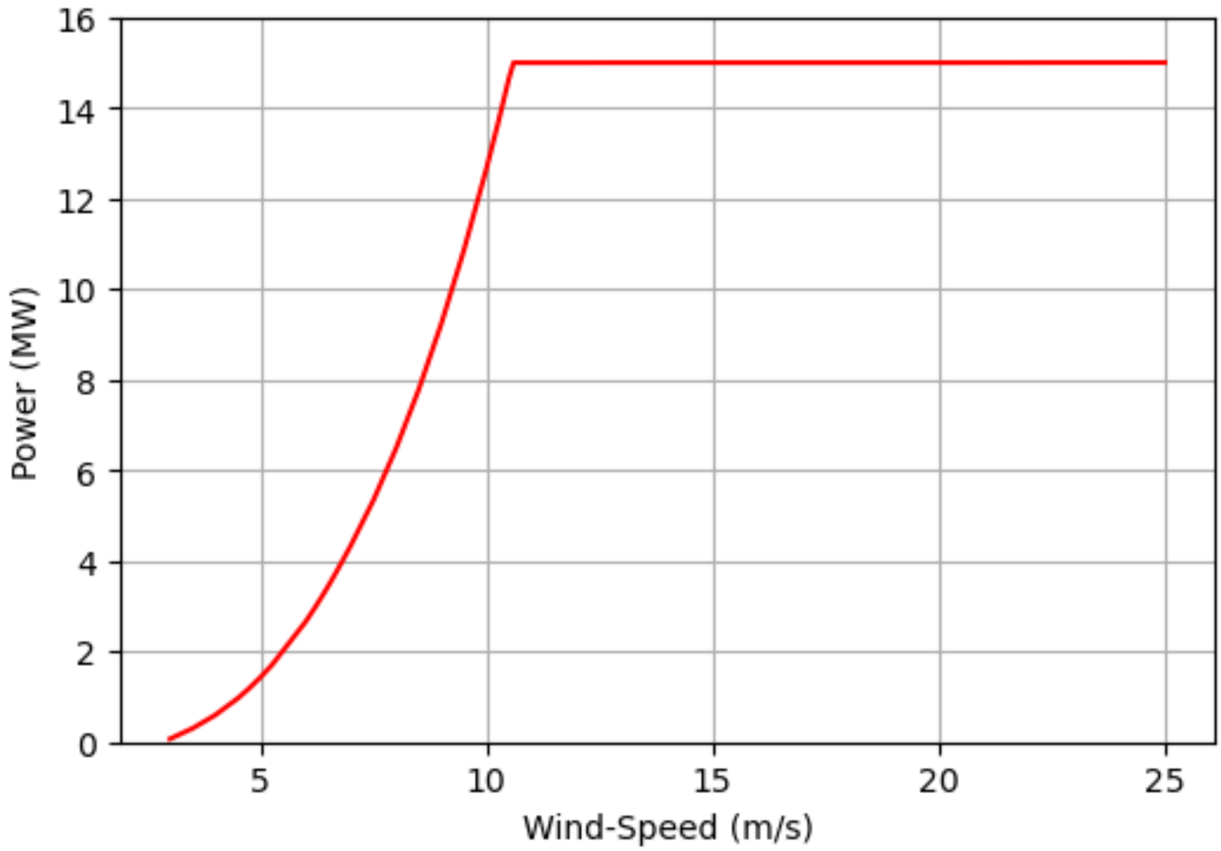


**Figure S1.** Power Curve for the IEA 15 MW Reference Wind Turbine (RWT) with cut-in and cut-off speeds at 3 and 25 m $s^{-1}$, respectively, and saturation wind speed of 11.2 m $s^{-1}$.

# S2 Seasonal Variability in Wind Resource

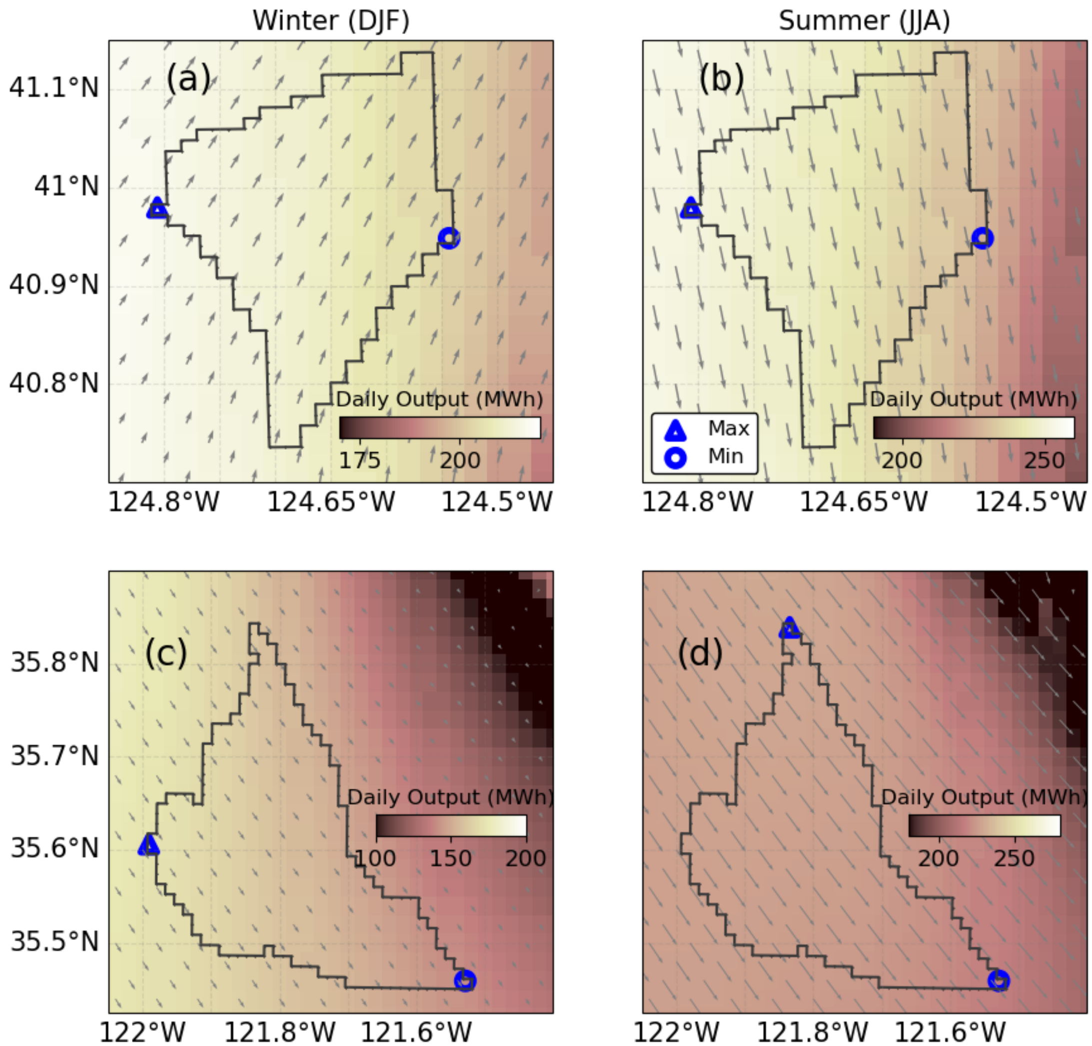


**Figure S2.** Seasonally Averaged daily energy output (colors), hub-height wind speeds (arrows) , and the locations of the grid-cells with maximum (MAX) and minimum (MIN) overall energy output for the (a, b) Humboldt and (c, d) Morro Bay WEAs. Left panels show mean values for winter months (DJF) and right panels show mean values for summer months (JJA).

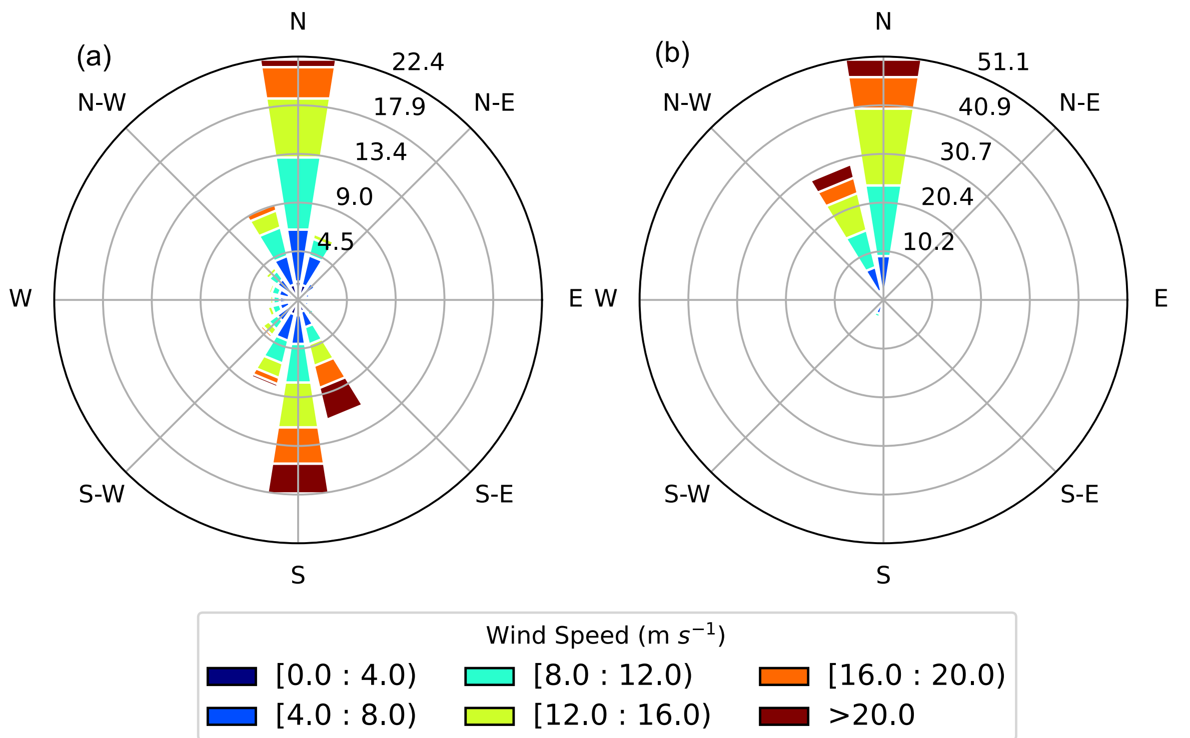


**Figure S3.** Wind roses for Humboldt Bay for (a) Winter (DJF) and (b) Summer (JJA).

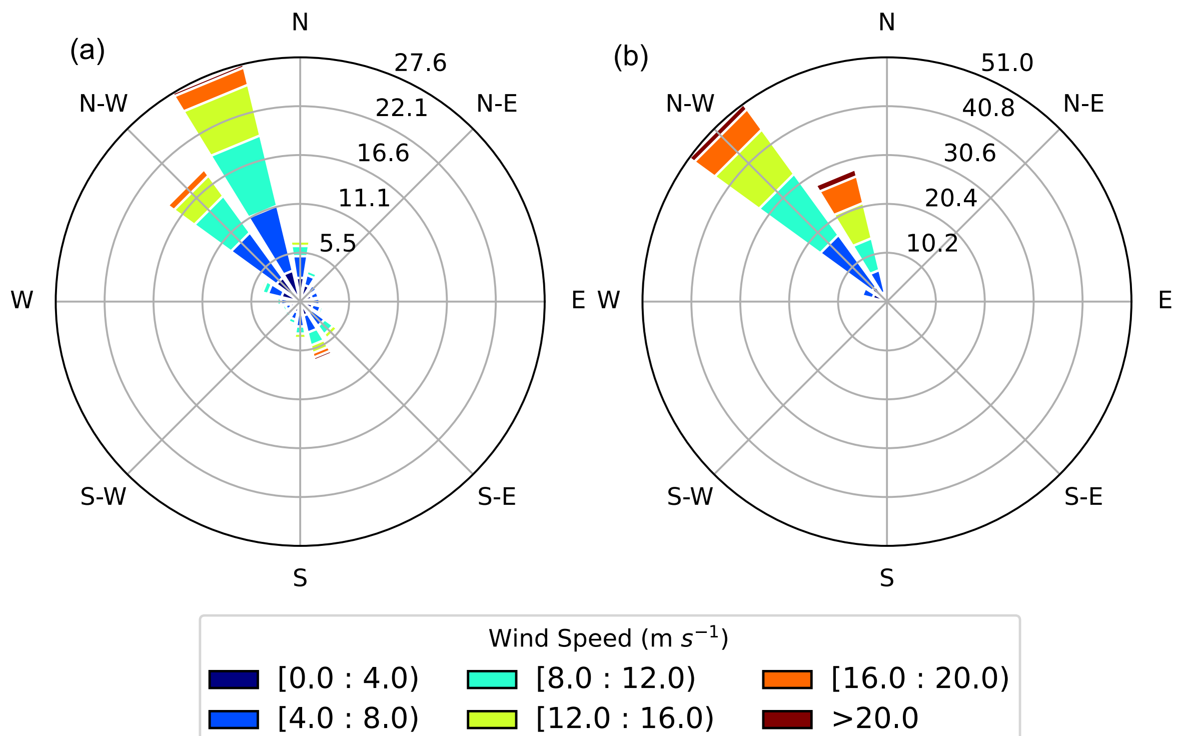


**Figure S4.** Wind roses for Morro Bay for (a) Winter (DJF) and (b) Summer (JJA).

# S3 Time Series of Daily Energy Output for MAX/MIN Energy Locations

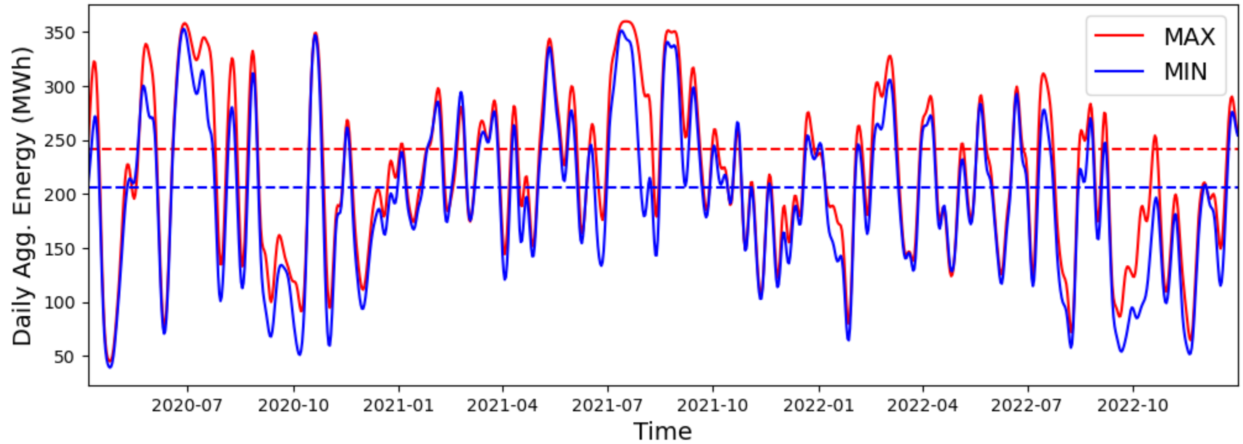


**Figure S5.** Time series of Daily Aggregate Energy Output for the points of MAX energy output (red) and MIN energy output (blue) for Humboldt. Overall mean energy output for both points are shown in dashed lines of the corresponding color.

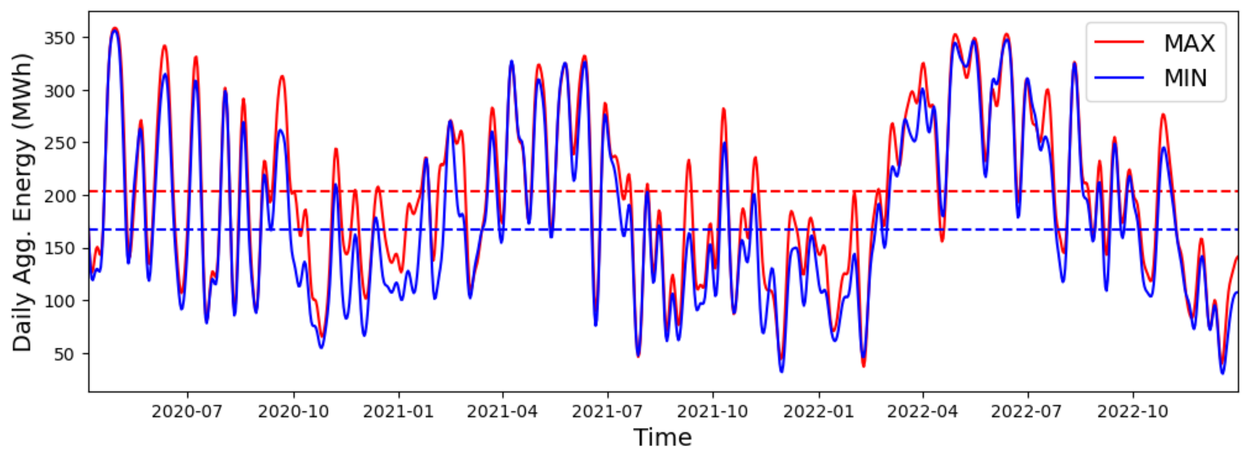


**Figure S6.** Time series of Daily Aggregate Energy Output for the points of MAX energy output (red) and MIN energy output (blue) for Morro Bay. Overall mean energy output for both points are shown in dashed lines of the corresponding color.

## S4 Wind Shear and Veer

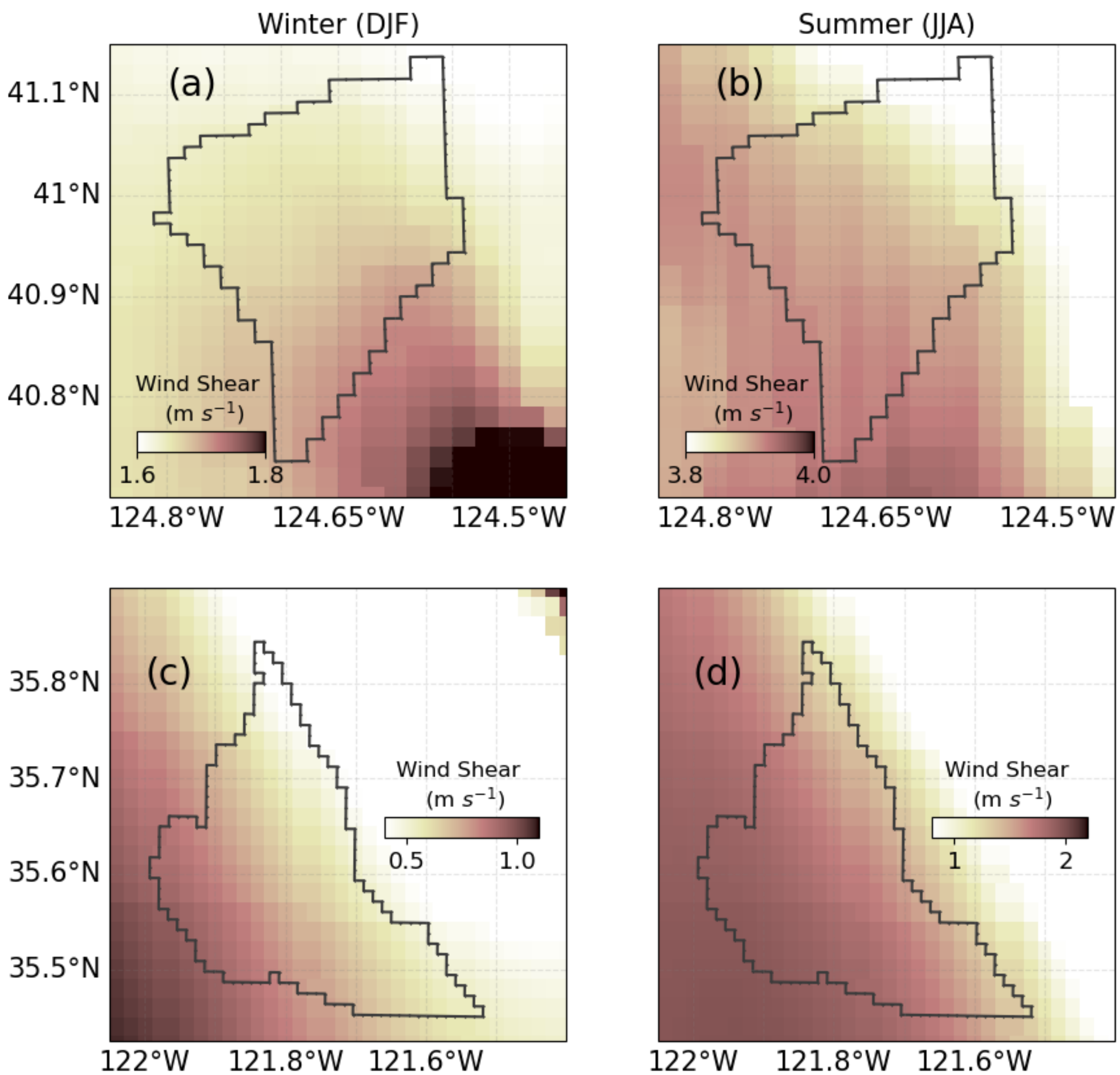


**Figure S7.** Seasonal mean rotor-layer wind shear ($ms^{-1}$) at the Humboldt Bay wind energy lease area (top panels) and Morro Bay wind energy lease area (bottom panels). Panels (a) and (b) show wind shear for winter (DJF) and summer (JJA) at Humboldt, while panels (c) and (d) show wind shear for winter and summer at Morro Bay.

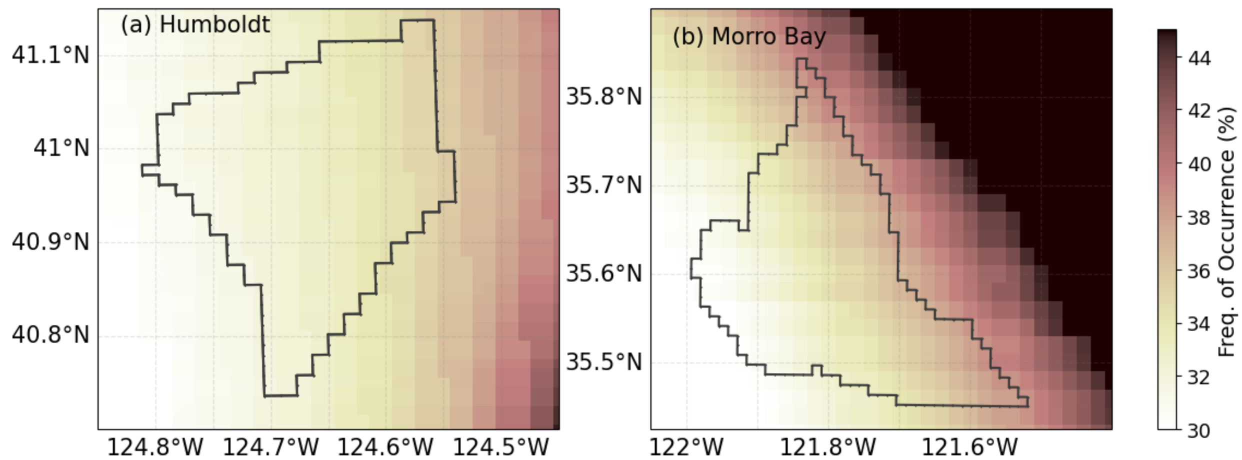


**Figure S8.** Frequency of occurrence of the PBL top heights being less than or equal to the halfway altitude of the wind turbine rotor layers (i.e., PBL top <= 150 m A.S.L) for (a) Humboldt and (b) Morro Bay wind energy lease areas.

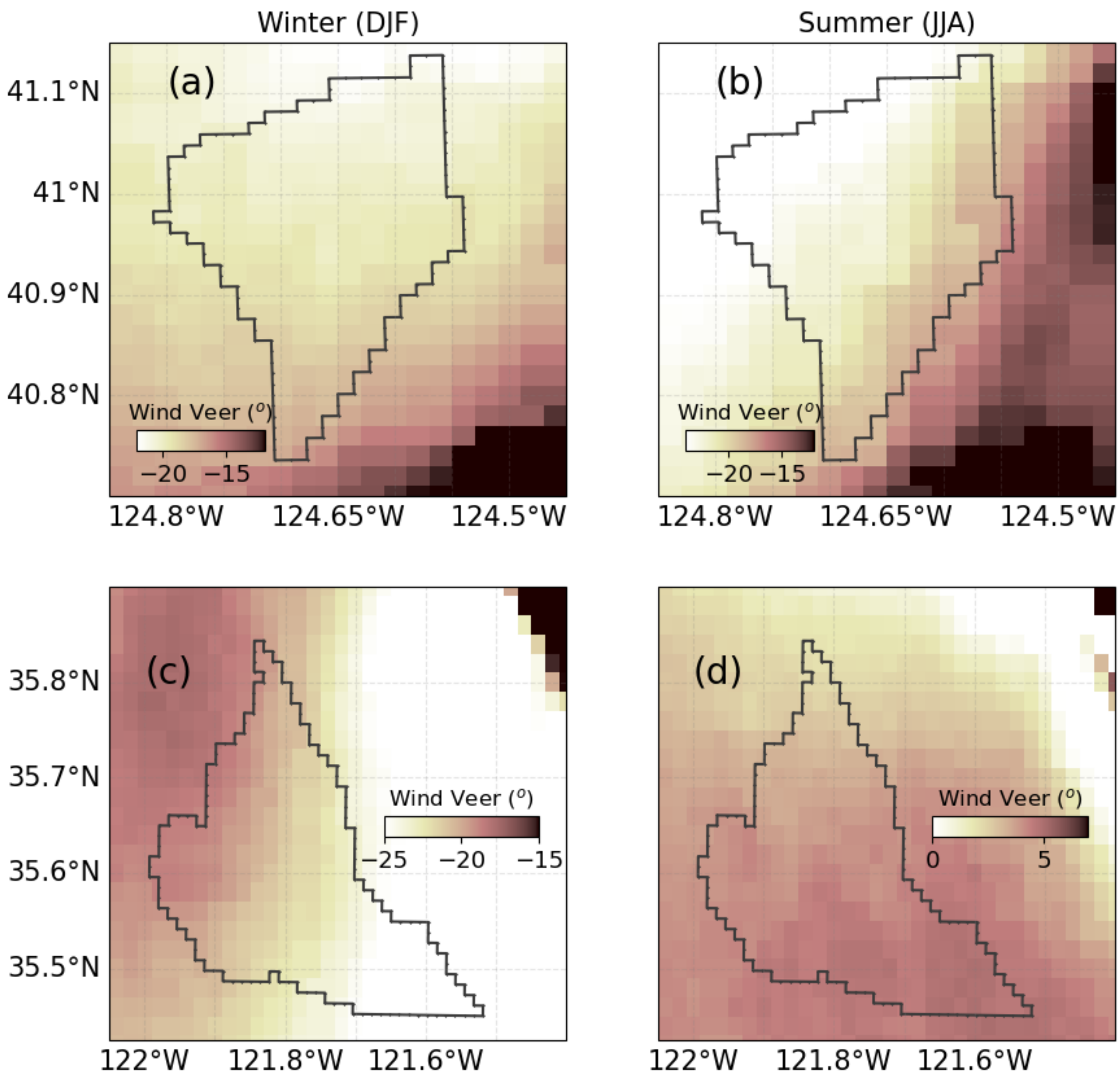


**Figure S9.** Seasonal mean rotor-layer wind veer (°) at the Humboldt Bay wind energy lease area (top panels) and Morro Bay wind energy lease area (bottom panels). Panels (a) and (b) show wind veer for winter (DJF) and summer (JJA) at Humboldt, while panels (c) and (d) show wind veer for winter and summer at Morro Bay.

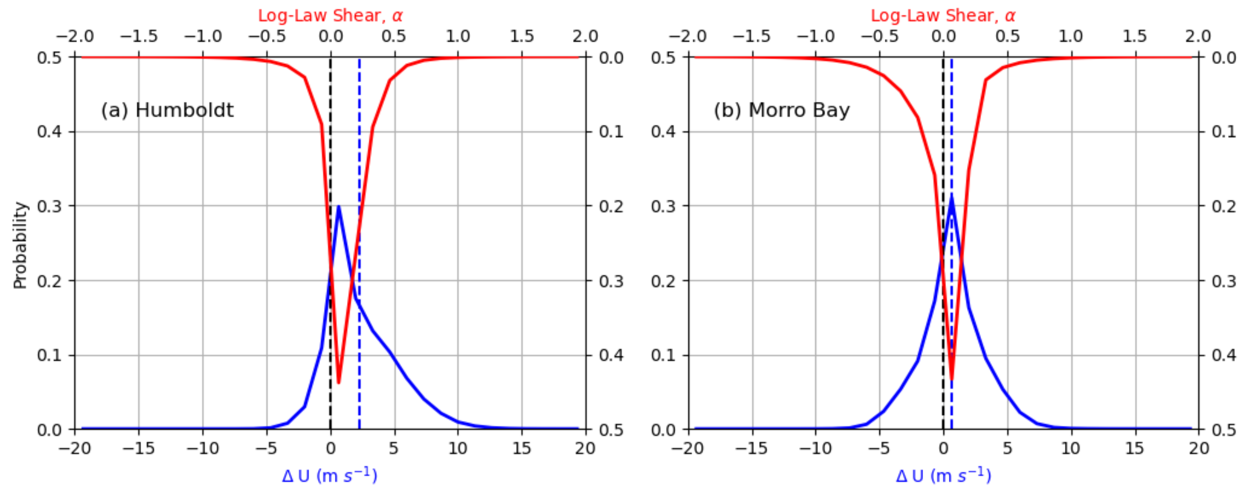


**Figure S10.** Histograms of wind shear expressed as (a) change of wind-speed across rotor-layer ($\Delta U, m\ s^{-1}$; blue) and (b) the log-law shear exponent, $\alpha$ (red) for Humboldt. Mean value for $\Delta U$ marked by a dashed blue line.

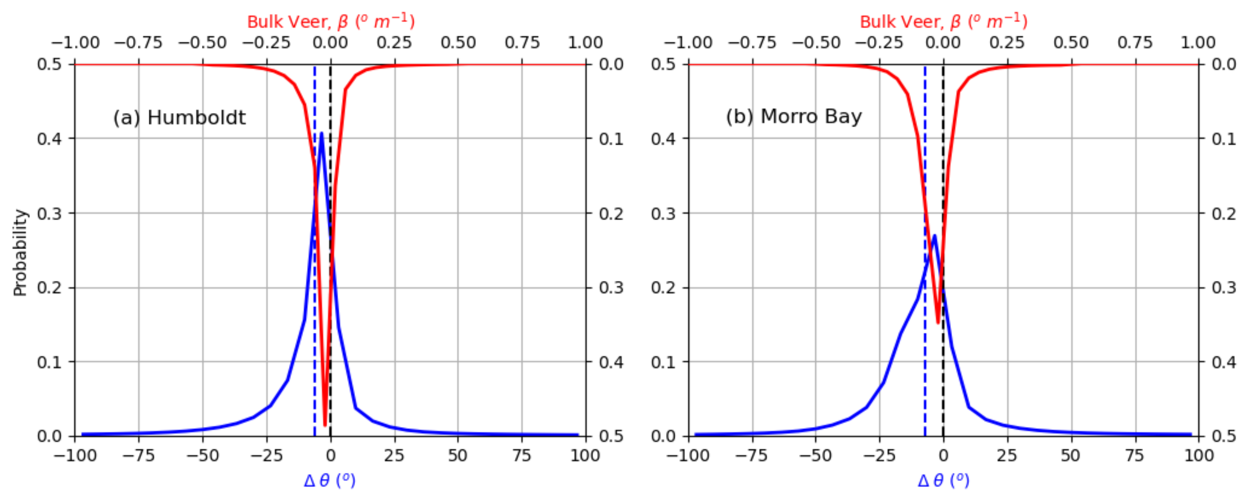


**Figure S11.** Histograms of wind veer expressed as (a) change of wind-direction across rotor-layer ($\Delta\theta, °$; blue) and (b) the bulk veer exponent, $\beta$ (red) for Humboldt. Mean value for $\Delta\theta$ marked by a dashed blue line.

# S5 Likely Impacts of Wind Shear and Veer on Energy Output

A simple estimation of the likely impacts of the combined effects of wind shear and veer on energy output at the Humboldt Bay Wind Energy Area (WEA) is designed based on the formulation by Choukulkar et al. (2015). According to this formulation, an equivalent wind speed ($\overline{U_{eq}}$) combining wind shear and direction fluctuations across the wind turbine rotor layer is defined as:

$$\overline{U_{eq}} = \sqrt[3]{\frac{1}{A}\sum_{i=1}^{N} \overline{U_i}^3 \left[1 + 3\left(\frac{\sigma_{ui}}{\overline{U_i}}\right)^2\right]\left[1 - \frac{\bar{\phi}^2}{2} - \frac{\sigma_{\phi i}^2}{2}\right] A_i}$$

where, $U_i$ and $\phi_i$ are the wind speed and direction for i-th level (levels span the wind-turbine rotor layer), $\sigma_{ui}$ and $\sigma_{\phi i}$ are the deviations in wind speed and direction for the i-th level and $A_i$ is the area spanned by the section of the wind turbine between successive levels.

We divided the rotor layer into 6 sections with levels for every 40 m intervals between 30-270 m. The deviations in wind speed and direction are calculated as the running standard deviation of wind speeds and directions over a 5-hour centered window. These metrics account for temporal fluctuations that influence power production. Power is calculated using the 15 MW IEA RWT power curve for both the hub-height wind speed as well as the equivalent wind speed ($\overline{U_{eq}}$).

Figure S12 shows that there is a strong relation between the wind shear and wind veer regime on the difference between hub-height and equivalent wind speeds ($\Delta U$), which can control the deviation of energy output ($\Delta E$) from our idealized conditions. Overall, $\Delta U$ is slightly negative for high shear (absolute value of rotor-layer shear > 2.5 m/s), leading to generally more output than under idealized conditions. $\Delta U$ is slightly positive for low shear (absolute value of rotor-layer shear < 2.5 m/s), leading to generally more output than under idealized conditions. Similarly, the absolute value of the threshold rotor-layer veer is 90° and Figure S12 shows that while the regime of veer controls the variance of $\Delta U$ and $\Delta E$, they do not influence the mean value of $\Delta U$ or $\Delta E$ in a systematic manner. These results should not be taken as an exhaustive statement on the impact of wind turbine shear and veer on wind energy output, but as a demonstration on how we seek to address this question in a future work, by leveraging NOW-23 multi-level wind speed and direction estimates at sub-hourly temporal resolutions.

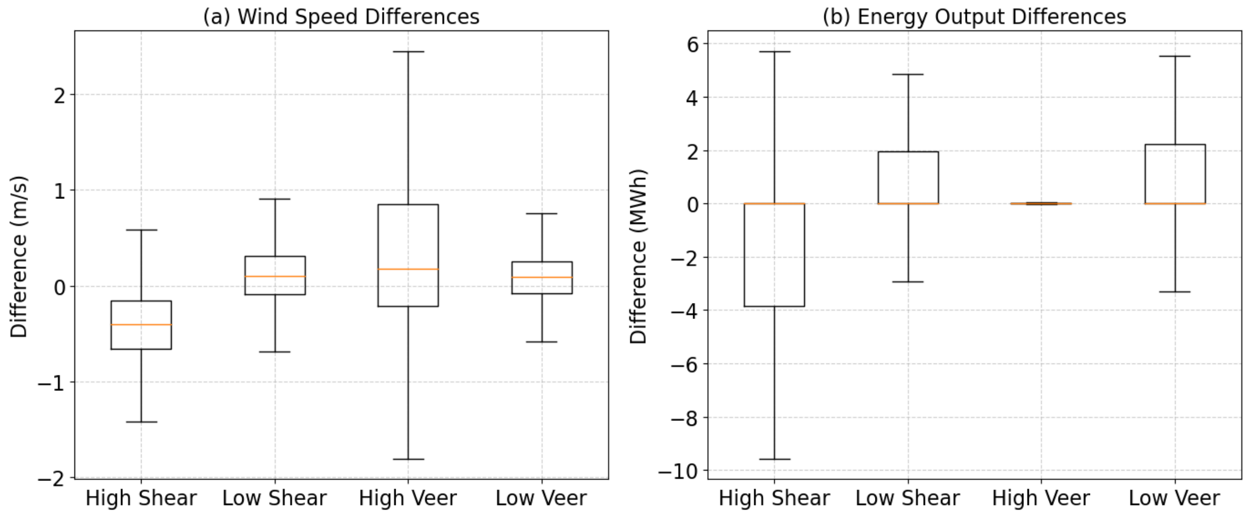


**Figure S12.** Histograms of difference between (a) hub-height and equivalent wind-speeds and (b) energy outputs computed for the hub-height and equivalent wind-speeds, at Humboldt Bay for regimes of high shear and high veer. Shown values are the hourly estimates from all grid cells within the respective WEAs.

## S6 Rate of Change of Power Output with Wind Speed

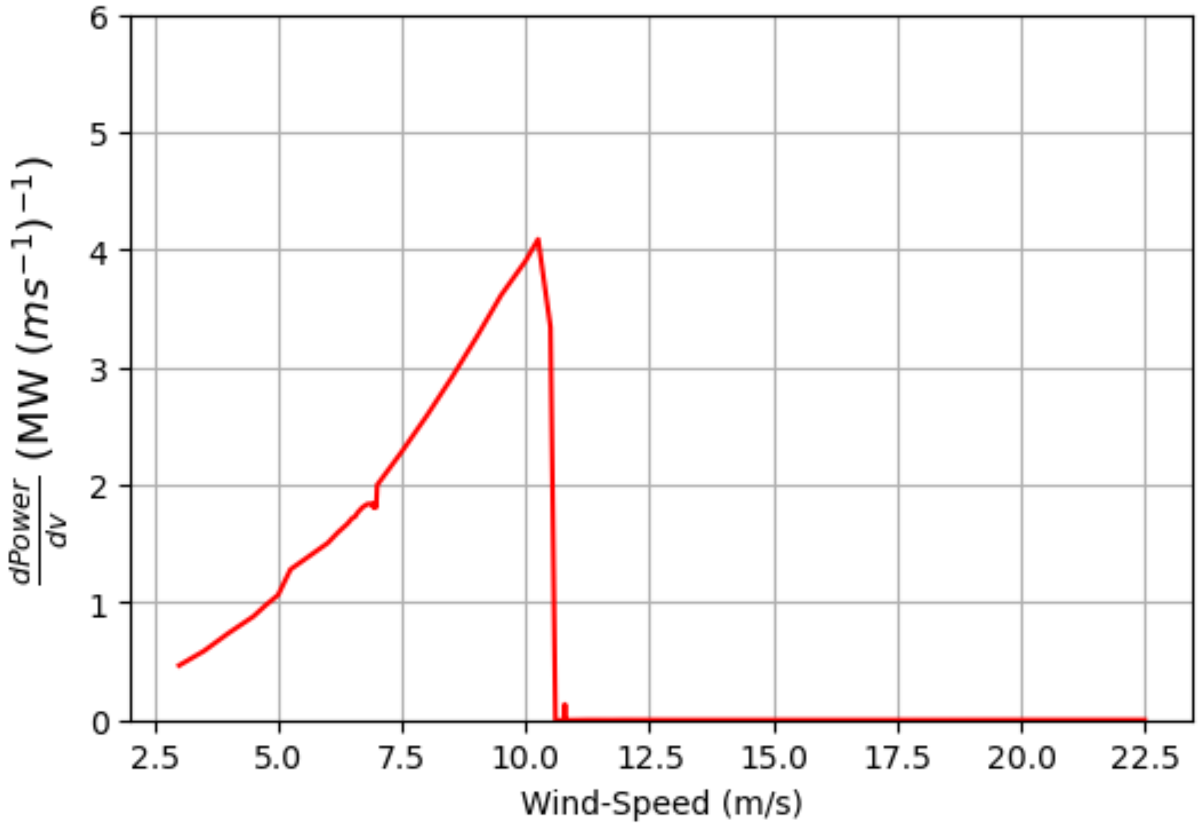


**Figure S13.** Profile of Rate of Change of Power with Wind Speed for the IEA 15 MW Reference Wind Turbine (RWT) with cut-in and cut-off speeds at 3 and 25 m $s^{-1}$, respectively and saturation wind speed of 11.2 m $s^{-1}$.

## S7 Variability of Wind Resource

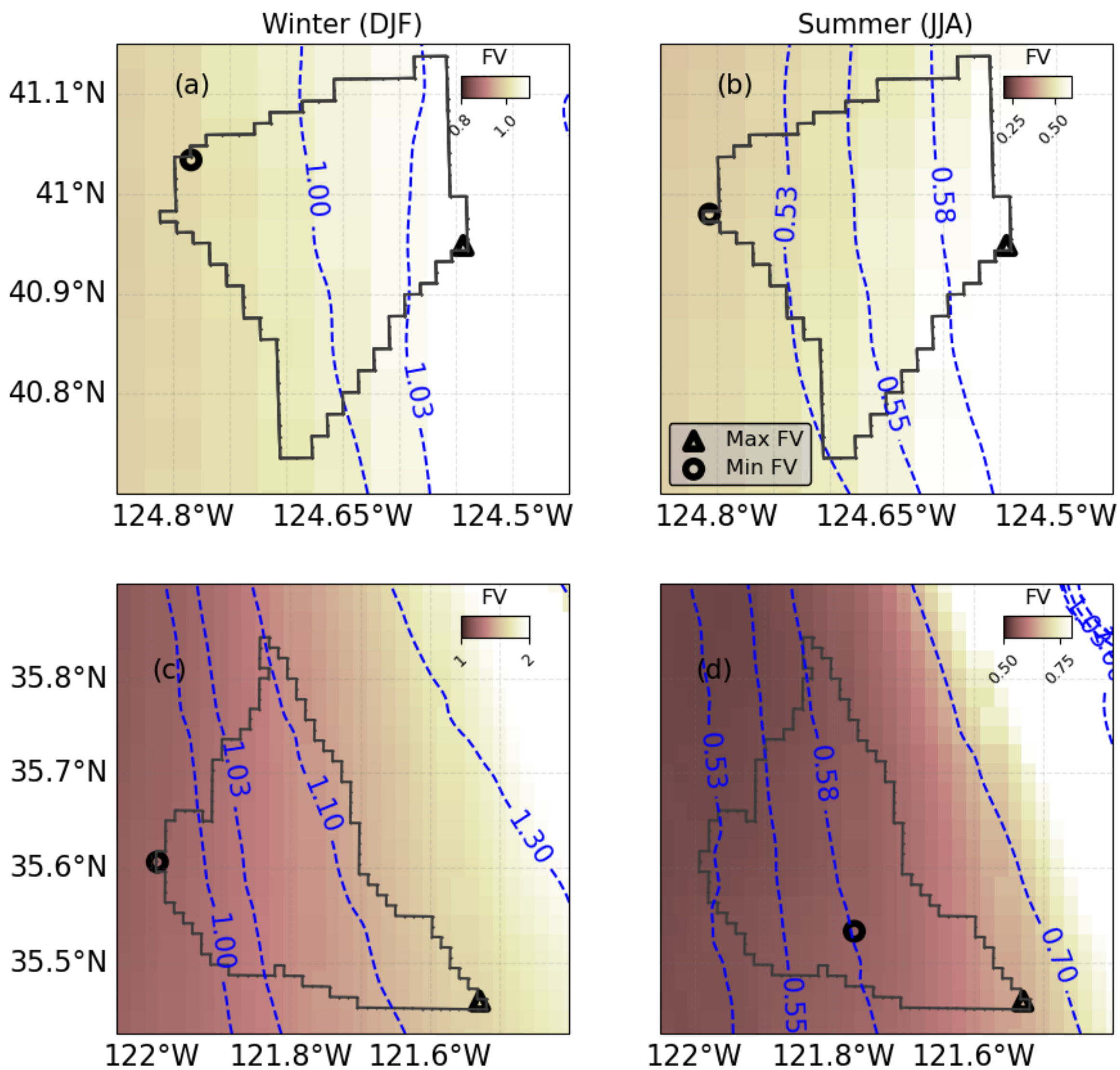


**Figure S14.** Seasonally Averaged Fractional Variability (FV) for Mean Daily Aggregate Wind Power Output (colors) and for hub-height wind speeds (contours) for Humboldt Bay (top panels) and Morro Bay (bottom panels) wind energy lease areas. Left panels show mean FV for winter months (DJF) and right panels show mean FV for summer months (JJA). Color scales are different for each panel. The locations of MAX and MIN seasonal mean daily power FV for each lease area are marked by a black triangle and ring, respectively.

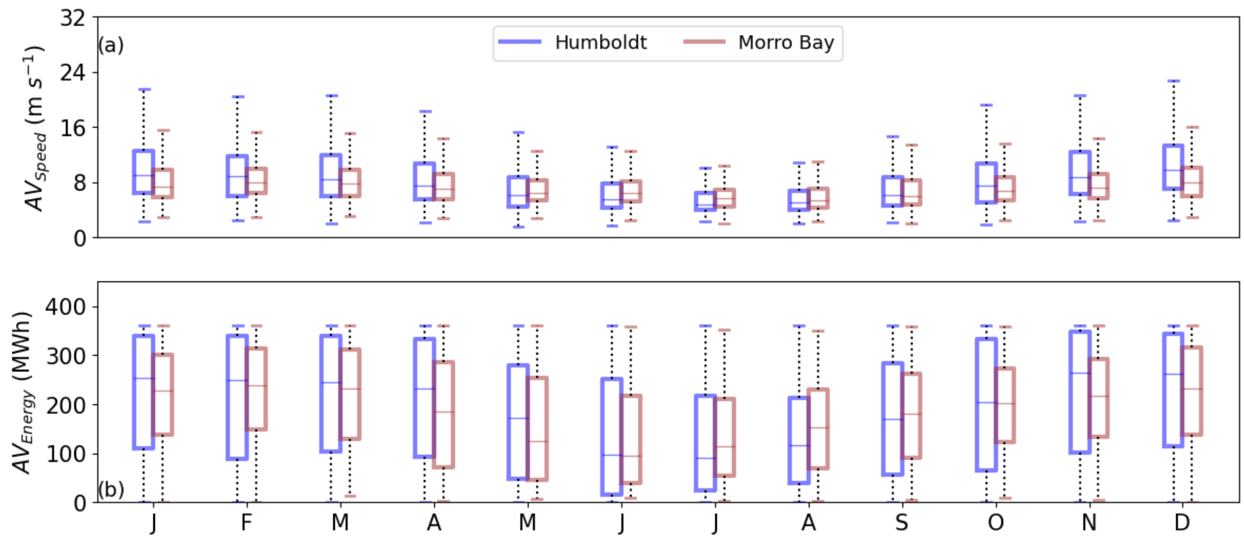


**Figure S15.** Monthly variation of absolute variability (AV) of (a) Hub-height (150 m A.S.L) wind speeds, (b) Power (MW), and (c) Planetary Boundary Heights (km) at Humboldt (blue) and Morro Bay (brown) wind energy lease areas.

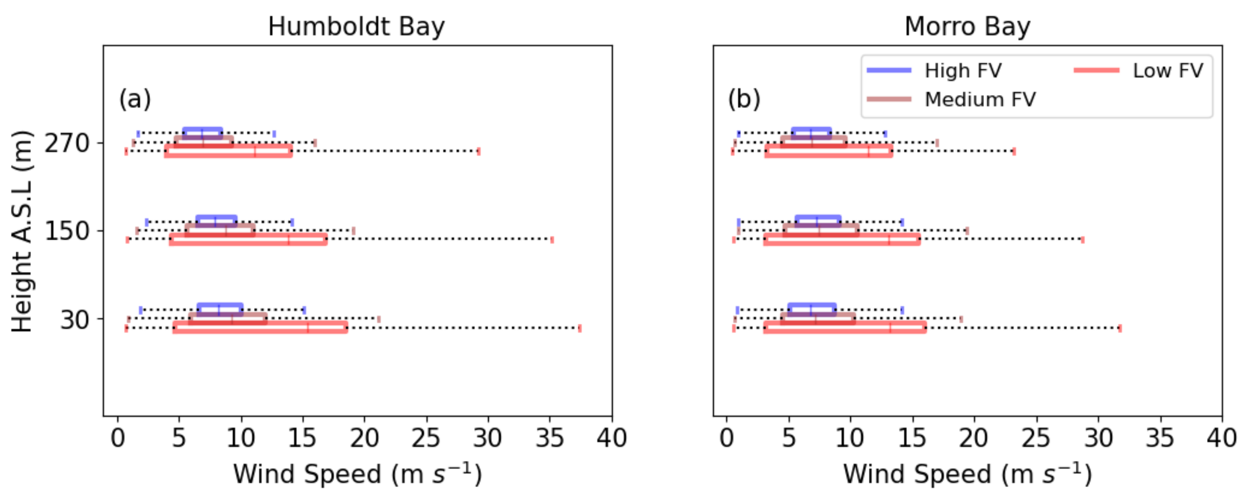


**Figure S16.** Variability of wind speeds with height across rotor layer at (a) Humboldt and (b) Morro Bay, for different regimes of fractional variability (FV) in wind power. High FV (blue) includes FV>1.5, 0.5>FV>1.5 is deemed Medium FV (brown) and Low FV (red) includes FV<0.5. Speeds are shown for bottom, hub-height and top of the rotor layer (bottom to top).

# S8 Sensitivity of Optimization to Choice of Power Curve

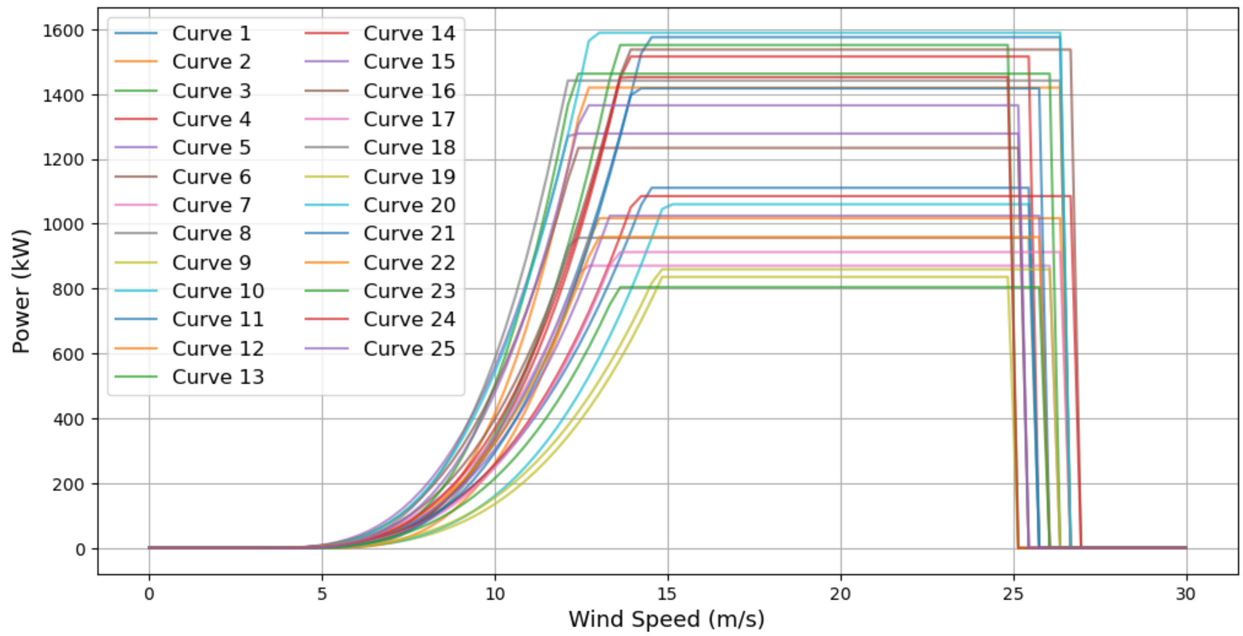


**Figure S17.** 25 Randomly Generated Wind Turbine power curves between rated powers of 8-16 MW, derived by choosing random values of cut-in and cut-out wind speeds and rated wind speeds and powers.

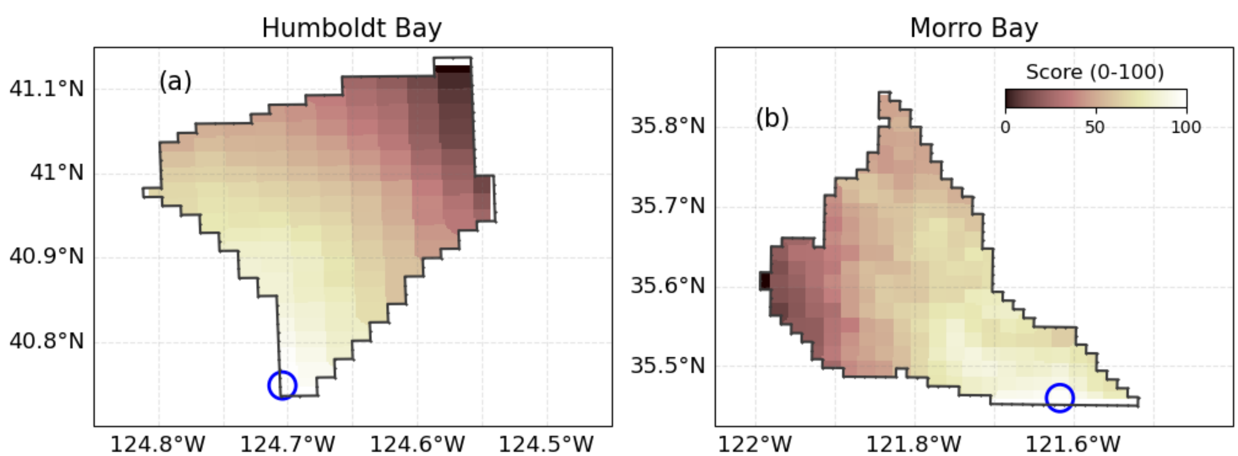


**Figure S18.** Mean Linear Optimization Score for grid cells at (a) Humboldt and (b) Morro Bay (brown) wind energy lease areas after optimizing for all 25 randomly generated power curves of Figure S10. The locations of the most optimal wind resource (MAX Score) at each wind energy lease area are marked with a blue circle. Note that in this case, the scores can lie anywhere between 0 and 100, but not necessarily exactly covering that range.