Geographical Variability of Summer- and Winter-dominant Onshore Wind

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Background

The large-scale deployment of renewable electricity resources for the power sector is a major driver of decarbonization and mitigation of climate change. Throughout the state of California, one of the biggest challenges in reaching a zero-carbon grid is identifying sources of electricity that match the seasonal profile of the load. Summer-dominant solar electricity generation can often be balanced by winter-dominant wind electricity generation. Together with long-duration storage, balanced solar and wind generation are well positioned to provide reliable renewable electricity. However, in some locations the wind may not complement solar energy so well.

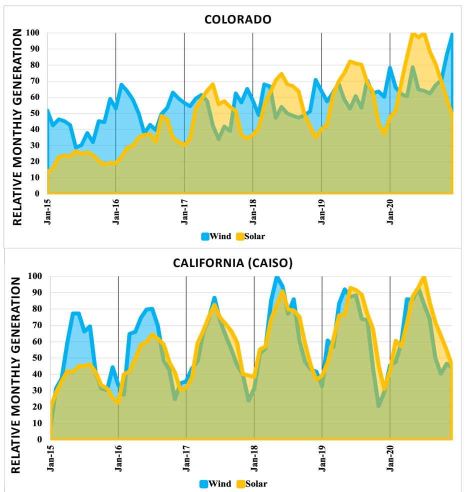

Fig 1: Seasonality of solar and wind generation for Colorado (top) and California (bottom)

Objectives

- To analyze the seasonality of the generation from existing and potential California wind plants
- To find the resource complementary to solar in California

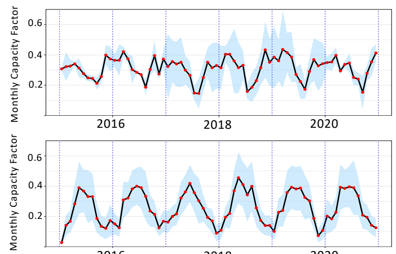

Fig 2: Monthly capacity factor (vertical dashed lines indicate January) for (a) winter-dominant (top) and (b) summer-dominant wind plants (bottom) in California from 2015 to 2020. The solid lines and blue shaded regions represent the mean and one standard deviation of all the analyzed plants, respectively, as calculated for each month

Data and methodology

The data we used includes CEC 1304 Power Plant Owner Reporting Database primarily for existing wind power plant capacity and monthly generation, EIA 860 and EIA 923 as a secondary source for some plant capacity and generation, California Protected Areas Database (CPAD) 2020b for exclusion of various protected areas, and NREL Wind toolkit for simulating wind generation. The grid size was taken as 0.02 decimal degree (DD) X 0.02 decimal degree points (approximately 2.22 km X 1.88 km), resulting in 107,670 locations analyzed in total.

$$W/S\ ratio = \frac{Generation\ in\ Dec + Jan + Feb}{Generation\ in\ Jun + Jul + Aug}$$

We simulated the 2012 monthly capacity factors for a number of winter-dominant and summer-dominant plants using 100-m wind speed data from the NREL Wind Toolkit. The simulated capacity factor and W/S ratio were calculated from those wind speeds using a wind power curve for a GE 2.5-120 turbine. We estimate winter-dominant high- quality wind resources in California with and without the exclusion of various protected areas based on the California Protected Areas Database (CPAD) 2020b.

Results

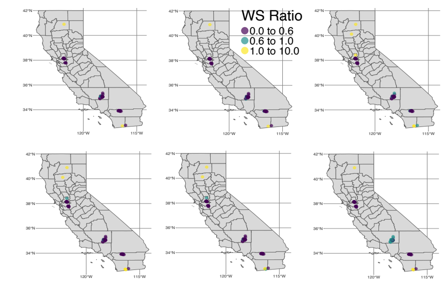

Fig 3: Measured capacity factor for the existing wind plants in California from 2015 to 2020

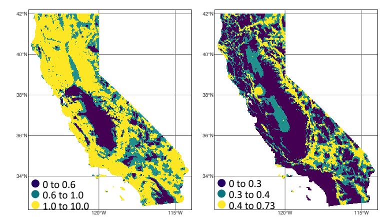

Fig 4: Current wind maps in California showing W/S ratio (left) and annual CF (right)

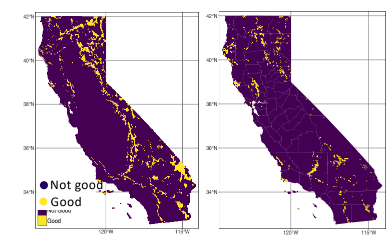

Fig 5: High-CF, winter-dominant, available wind power potential (CF > 0.4, W/S ratio > 1) without (left) and with (right) excluding regions with slope > 20 degree, and protected areas.

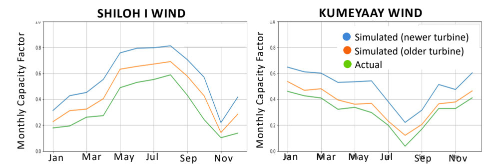

Fig 6: Comparison of monthly CF for simulated and actual generation for a summer (left) and winter (right) dominant plant

Conclusions

- The ratio of winter-to-summer generation can vary from more than 2 to less than 0.4, with the observed seasonality for each location being relatively constant from year to year
- Almost 60% of the state has wind resource that is stronger in winter than in summer, despite today's observation of strongly summer-peaking wind electricity generation
- Disregarding the economic feasibility, we estimate about 22 GW of winter-dominant plants could be sited on available land. These represent 23% of the total potential.

Types	Potential (GW)	Annual generation (TWh/year)	Mean W/S ratio	Area (km^2)
Total Potential	107	428	1.44	35,664
Potential in available areas	25	100	1.42	8,396
Potential in available areas excluding steep slop areas	22	74	1.40	6,437

Table 1: Wind power potential in winter-dominant, high-quality wind resource areas

Acknowledgments

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