Demonstration of WindSim Park Optimization

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Abstract

The extraordinary surge in wind energy development over the past two decades has been accelerated by the abundance of locations with promising wind resources. These locations have been aggressively sought-out due to their low-risk of inefficiency; nevertheless, as the availability of such sites continues to dwindle, future development depends on the exploration of areas with higher-risk wind resource (i.e., complex terrain). These higher-risk sites are inevitably much more sensitive to pre-construction technical decisions (i.e. turbine layout, hub height, turbine selection, etc.) and accurate wind resource characterization. In this presentation we comment on the importance of optimizing turbine positions while quantifying potential AEP improvements for a number of existing wind farms.

Method

The objective of this study is to quantitatively understand how potential wind farm AEP can be optimized through high-resolution wind turbine micro-siting. We couple 3D CFD simulation output with an optimization algorithm to compare the AEP of existing wind farm layouts against optimized configurations. Limiting factors inherent to the local wind climatology, as defined by the International Electrotechnical Commission (IEC) standards, are incorporated. Our findings highlight the advantages of early-stage site analysis as the industry moves towards development in higher-risk wind regimes.

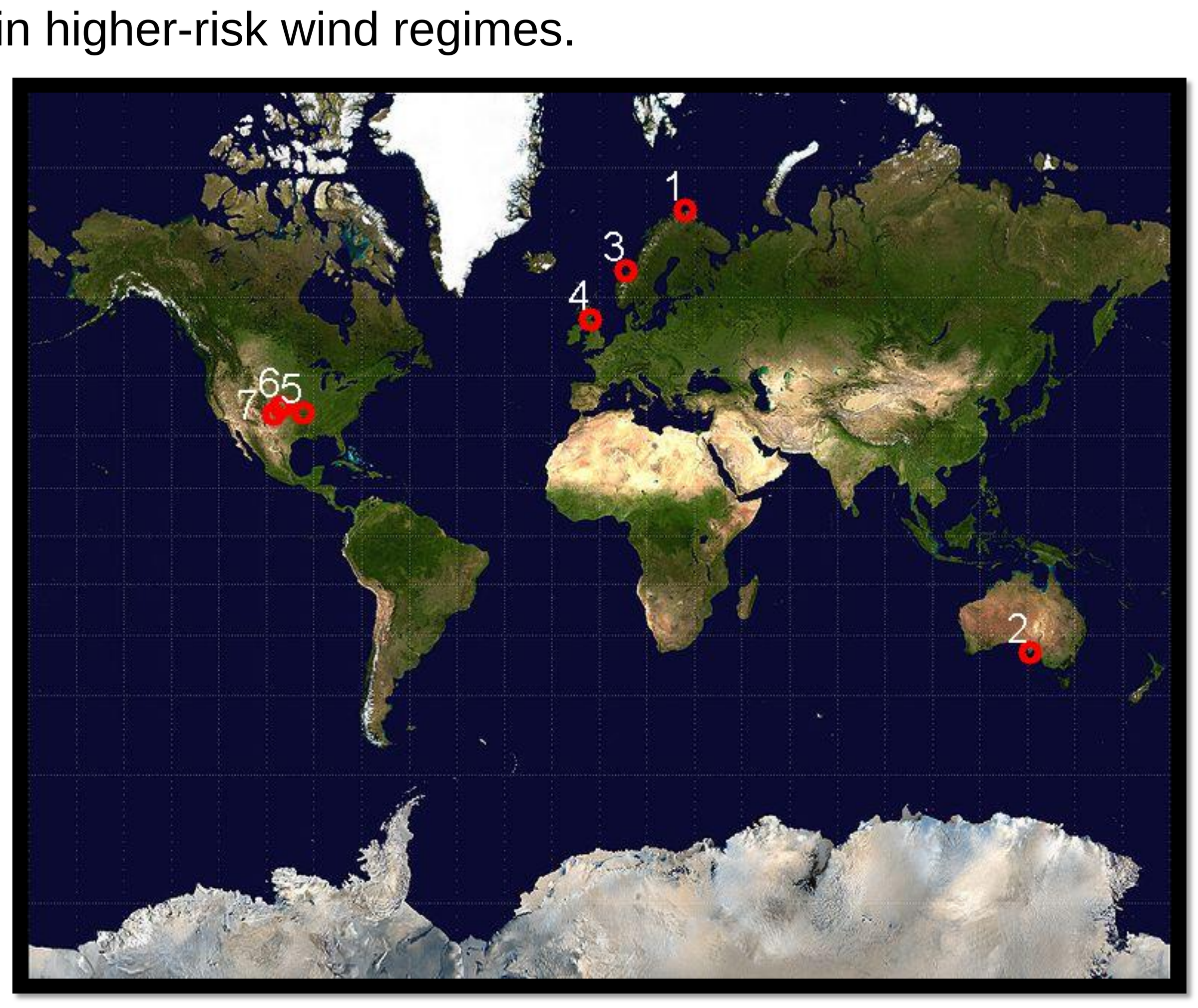

Fig. 1: Locations of the seven sites used in this study.

Optimization Details

- The optimized layout of each wind park was constrained by the standard IEC standards
- The hub heights corresponded to the real hub heights of each wind farm (i.e. 42 – 82 m above ground level)
- A standard turbine power curve and rotor diameter was used for all cases
- CFD simulations were scaled using virtual climatology data derived from MERRA reanalysis

Results

From our analysis the following observations can be made:

- AEP increases of primarily 3 to 10% were achievable through the park optimization process; however, there was an outlier or 32% for Case 5 mainly due to the large area that the original park occupied.
- Wake loss decreases of up to 7% were found; however, for one case (6) wake losses increased slightly despite the fact that overall AEP increased.
- Overall, the magnitude which a wind park can be optimized is closely related to the size of the land area available; in other words, expanding the boundaries of the wind park slightly can significantly improve power production for most cases

Results (cont.)

Table. 1: Summary of the cases and comparison of the power statistics from the original and optimized turbine layouts.

Case	Site	Location	# of Turbines	Original AEP (GWh/y)	Original Wake Loss (%)	Optimized AEP (GWh/y)	Optimized Wake Loss (%)	AEP Increase (%)
1	Kjøllefjord	Northern Norway	17	146	5.13	153	1.85	4.79
2	Cathedral Rocks	Southern Coast of Australia	33	229	4.63	242	3.02	5.68
3	Hitra	West Coast of Norway	23	120	4.01	125	2.55	4.17
4	Black Hill	Eastern Scotland	22	138	10.47	153	3.70	10.87
5	U.S. WF 1	Mississippi River Valley	60	133	2.76	176	2.53	32.33
6	U.S. WF 2	U.S. Great Plains	162	952	2.63	985	3.28	3.47
7	Wildorado	Northern Texas	70	489	5.54	505	3.19	3.27

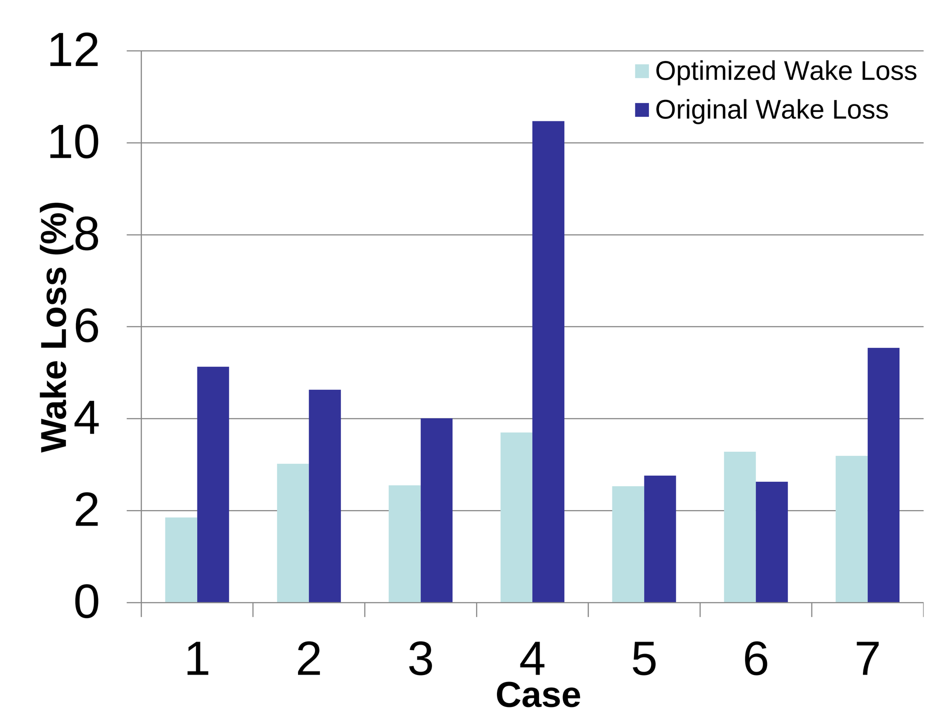

Fig. 2: Original and optimized wake losses for each case.

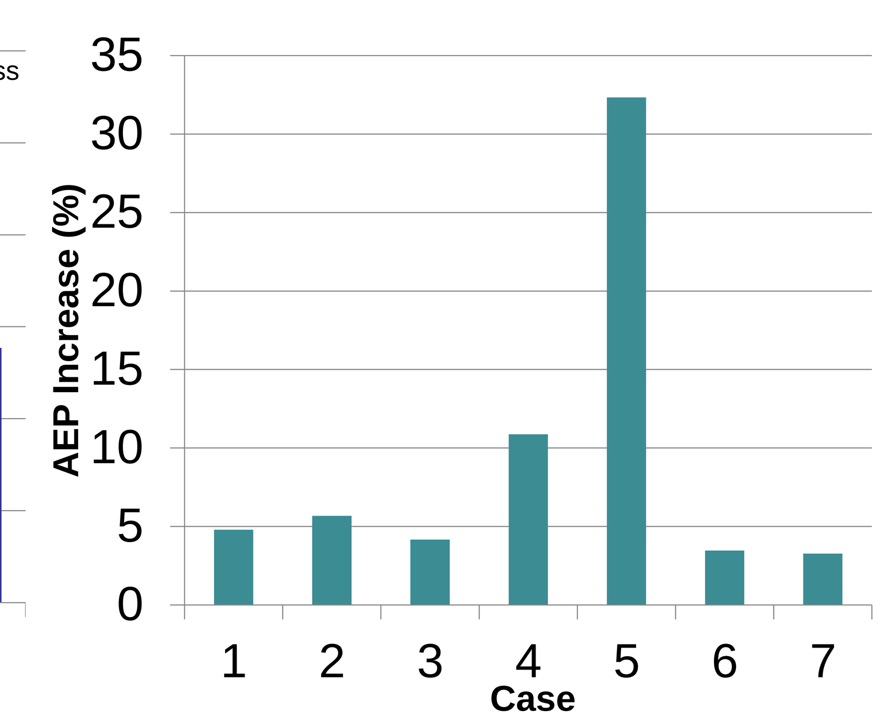

Fig. 3: Increase in annual energy production (AEP) after park optimization.

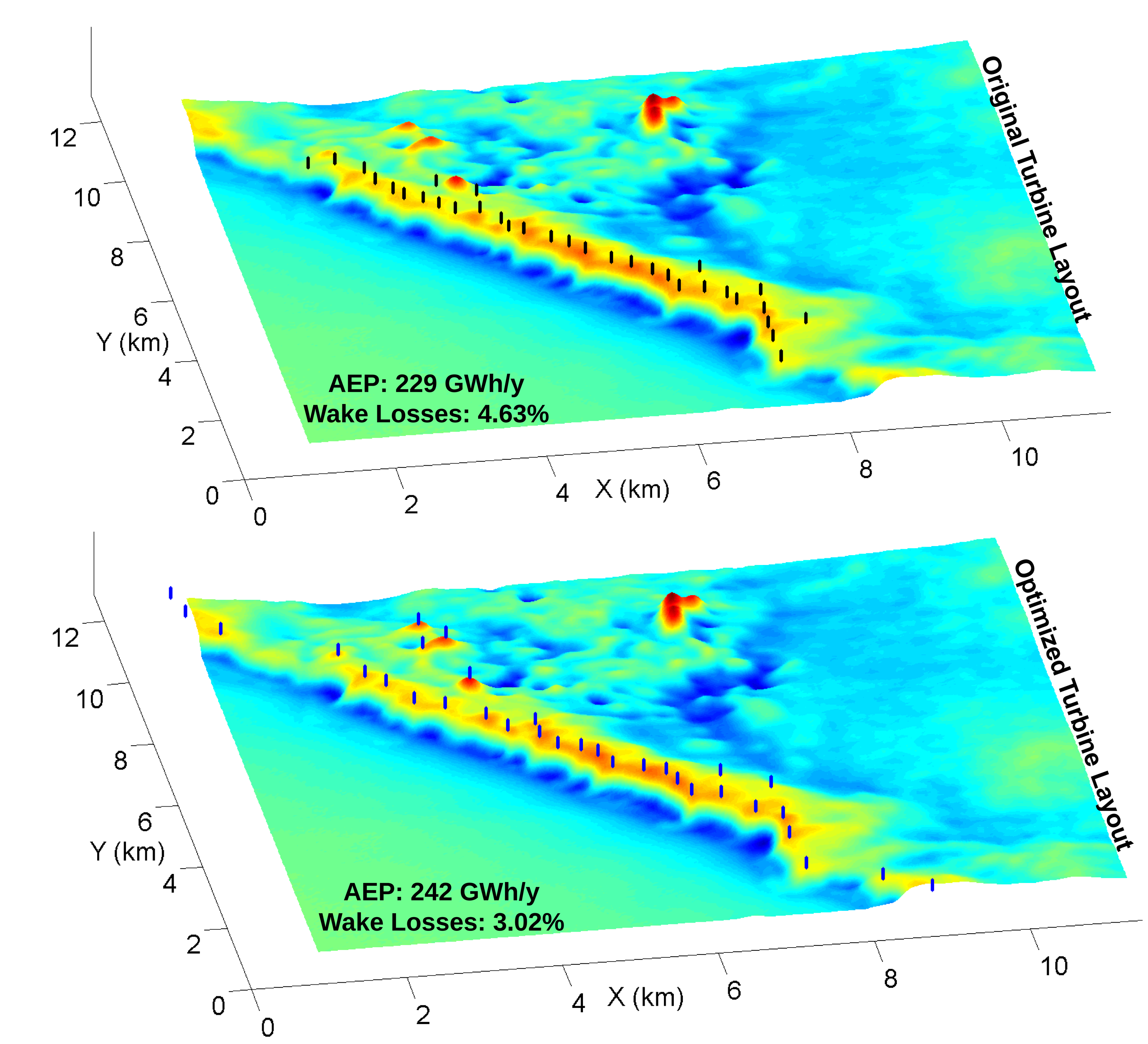

Fig. 4: Mean wind speed at hub height (60m AGL) for Case 2 overlaid with original layout (top) and optimized layout (bottom).

Conclusions

In summary, we have quantified the value of the WindSim Park Optimizer with respect to potential AEP increases. For the cases investigated, we have found AEP increases ranging from 3% to 32% and wake loss decreases up to 7%. Also, the capability of the park optimizer to produce meaningful park layouts depends strongly on the accurate prescription of all relevant geological and IEC constraints.