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Reply on RC1

Charles Tripp et al.

Author comment on "A simplified, efficient approach to hybrid wind and solar plant site optimization" by Charles Tripp et al., Wind Energ. Sci. Discuss., https://doi.org/10.5194/wes-2021-54-AC1, 2021

Thank you for your careful review and insightful suggestions. Please see our responses and proposed strengthening actions below.

On wind turbine choice:

We chose the default turbine in the SAM library, knowing that it could be replaced with any size turbine desired. For this paper, the nameplate capacity of the wind and solar were fixed, and so too was the number of turbines. Using 2MW turbines we would have 37 or 38 turbines to place, and this would have made the turbine grid less dense. Without running it, it’s hard to say exactly which aspects would change the most in the resulting layout candidates. However, the overall layout optimization problem and the effectiveness of this approach would be similar.

On wind to solar capacity ratio:

The nameplate wind capacity was fixed at 75 MW, which is roughly half of the typical pure wind power density on the circular site (approximately 5.2MW/km2 over a 3 km radius circle). Because the wind resource was stronger than the solar resource on these sites we chose a solar capacity of 50 MW. **We will add a breakdown of the solar and wind contributions to AEP for the layouts shown. We will add discussion of the impacts of the wind to solar ratio on the layouts found. Time permitting, we will additionally add result set and discussion using the opposite wind to solar ratio;** it would indeed strengthen our analysis to characterize the impact of solar-dominated capacity constraints on the layouts produced.

On the choice of optimization objective:

We aim to provide a proof of concept that stochastic optimization of low-dimensional parametrized layouts is an effective method for producing efficient hybrid plant layouts. With that in mind, **we chose to optimize AEP because it provides a clear yet challenging objective function without the additional complexity and sensitivity to assumptions which an objective such as net present value brings with it.** NPV introduces many pricing and cost assumptions and the resulting layouts can be highly sensitive to these assumptions, which could easily conflate and cloud the proof-of-concept we aim to demonstrate with this work. Since we fixed the nameplate capacities and we did not use a detailed cost model, the costs of each candidate don't change. Revenue in an NPV objective would change depending on how prices vary with time, whereas AEP with fixed capacities can stand-in for a constant price of energy, therefore providing an objective which is both similar to a practical objective like NPV, but simple and clear enough to provide a proof-of-concept. **We will add a passage to the document clarifying our rationale for using an AEP objective.**

On the site selection:

Pearson Correlation Coefficient is most commonly used in this type of analysis (https://www.sciencedirect.com/science/article/pii/S0038092X19311831, https://www.nrel.gov/docs/fy13osti/57816.pdf, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8749030). It is true that Pearson Correlation Coefficient relies on the assumption of bi-variate normality for the two variables while no distributional assumptions are required for Spearman's Rank Correlation Coefficient. However, Spearman's CC is generally considered more appropriate for use on ordinal (i.e. ranked) data. Furthermore, Pearson is most commonly used for timeseries data. When we examined the dataset closely using multiple correlation coefficients (including both Pearson and Spearman), Pearson CC was most reflective of the complementarity seen. **We will add additional discussion of our choice of correlation coefficients and additional supporting details on the example site selection process to the document.** Including the equation and nature of the data used in selecting the test sites. Both wind rose and resource correlations impacted our AEP objective; it is expected that different site layouts would be found for different resource correlations or wind roses. We will amend our analysis of the results to reflect this fact.

On the interpretation of results:

You are correct: placing solar on the interior of the site can allow for greater separation between turbines and therefore reduce wake losses. When this is done in a way which reduces wake losses by more than the flicker and shading losses which might be incurred by an interior placement, the interior solar placement layout is superior to a southern boundary placement. *In this sense, the largest benefits from allowing flexible solar placement are typically in reducing wake losses.* **We will update our text to clarify this point, and to motivate the flexible placement of the solar region.**

The prior distribution on the solar region placement ("solar y position") used to initialize the optimization is set in a way which biases the search towards exploring candidates which place the solar region along the southern boundary of the site. In Figure 10's optimizer trajectory plot we see that the optimizer indeed often finds good layouts which have solar regions on or near the southern boundary of the site. However, as seen in Figures 5-8, these are not the only high-performance layouts for any of the four example scenarios.

Additional concerns and tradeoffs must be made even if layouts are constrained to solar along the southern boundary, such as where along the boundary to place the solar region ("solar x position"), what shape and density of solar region to use as lower solar densities reduce internal shading but also increase wake losses by increasing turbine density ("solar gcr" and "solar aspect power"), and how large of a setback to use between the solar region and turbines, which trades off turbine-solar shading and flicker losses for wake losses ("solar x buffer" and "solar s buffer").

Stanley et al.'s "Massive simplification of the wind farm layout optimization problem" demonstrated that the turbine parameterization we used performs competitively with non-parameterized state of the art layout optimization. Therefore if we constrained solar placement to a fixed reasonable placement along the southern boundary, and only optimized the turbine layout, we will find solutions which are comparable with a state-of-the-art turbine layout optimization, where the solar region is placed at a fixed region along the southern border of the site. **We will augment our results and discussion with these results, thereby isolating and demonstrating gains due to flexible solar placement.**

As with many turbine layout optimization methods, the results are moderately sensitive to the wake model. However, the restrictions imposed by parameterizing turbine placement mitigate wake model sensitivity in comparison to a non-parameterized approach. A non parameterized optimizer's flexibility allows it to make micro-siting adjustments, moving individual turbines just right to exploit weaknesses in the wake model. **In contrast, our parameterized turbine grid simply cannot make these micro-adjustments and therefore is less likely to generate layouts which depend on artifacts of the particular wake model used and which may have little real-world benefit.** One way of thinking about this effect is that the parametrization applies a strong regularization to the optimization problem, which increases the robustness of solutions and decreases solution sensitivity to the peculiarities of any models used.

Thank you again for your careful review and comments. We will reply again once the manuscript has been revised.

Best,

Charles Tripp

Please also note the supplement to this comment:
https://wes.copernicus.org/preprints/wes-2021-54/wes-2021-54-AC1-supplement.pdf