

## Reply to RC2

Thanks for the reply. I think there is a misunderstanding. I do not ask for any additional model runs – I understand this is out of scope and also not necessary. I just ask for minor but important rephrasing of the manuscript.

I agree with the authors that uncertainty refers to the lack of knowledge of the true state of the system (so change model parameters or inputs within their range of uncertainty and look how the output varies) while sensitivity assesses how sensitive the model output is to certain parameters or inputs (that can take any value either within realistic bounds or not). This study essentially boils down to evaluating the impact of different driving data for the regional climate model—namely ERA5 and ERA-Interim—as well as studying the sensitivity to the implementation of 3.6 MW versus 15 MW turbines at the same capacity density (and they added a sensitivity analysis to the correction factor to the turbulence production term). For the reasons I mentioned in my previous review, it is in my opinion not a full uncertainty analysis that quantifies the total range of uncertainty of model output. However, even if the authors and the editor agree on keeping the word uncertainty in the title, I offered in my previous review an easy to implement alternative with little change to the manuscript, which I still feel necessary to avoid any misinterpretation of the paper. I copy and paste from my previous review:

**(1) Be transparent that this represents only part of the overall uncertainty. At the minimum, the authors should clearly state in the abstract that the goal is not to perform a full uncertainty analysis, but rather to explore some sources of uncertainty: (i) the uncertainty arising from the use of different reanalysis datasets, and (ii) the uncertainty arising from the change in turbine type (from 3.6 MW to 15 MW) while keeping the same layout and capacity density (iii) analyse the impact of applying a correction factor (0.25) to the turbulence production term from the Fitch wind farm parametrization.**

The manuscript has been revised to explicitly clarify the specific sources of uncertainty addressed in this study.

The revised title now reads:

“Uncertainty in North Sea Offshore Wind Power: Contributions of Reanalysis Forcing, Turbine Type, and Wake Parameterization”

In addition, the abstract has been modified to better frame the scope of the analysis. Line 6 now reads:

“... However, the associated uncertainties are often only partially addressed due to the complexity and diversity of contributing factors, ranging from technical aspects such as turbine geometry and layout to atmospheric processes across multiple scales, from small-scale turbulence to mesoscale dynamics. ...”

**(2), the conclusion/discussion part should discuss the points raised in the reply of the authors to me in the previous review round. They write a very good text about it in the reply, but this did not end up in the manuscript—particularly that there are numerous other sources of uncertainty. Transparency is important here.**

We extended the list of examples of the vast number of uncertainty sources in our conclusion. Our original text in Lines 440-442:

The quantification of uncertainties in generated power extends beyond the sources considered in this study. Additional factors, such as other driving conditions, inaccuracies in turbine coefficients, and temporal or spatial and vertical resolution of the model, among others, may also contribute significantly to overall uncertainty.

Now it reads:

We emphasize that the uncertainty sources examined here represent only a subset of the broader uncertainty space associated with offshore wind power estimation. Additional uncertainties exist from technical factors like turbine geometry, layout, and performance characteristics. From atmospheric processes across multiple scales, such as wind profile representation, atmospheric stability, small-scale turbulence, and atmospheric dynamics. Also Model-related uncertainties stem from turbulence parameterization, spatial and temporal resolution, structural differences among modeling approaches, and the representation of interactions between neighbouring wind farms, etc.

**(3) that the lower end of their uncertainty estimate is not realistic, since these turbines will not be considered in future parks.**

We acknowledge that the lower end is not realistic. To clarify the rationale behind our simulations, we added the following paragraph in Subsection 3.3 "Wind Farm Scenarios" line 203:

Although the 3.6 MW scenario is unrealistic for future deployment, it provides a controlled baseline for comparison. By keeping all other factors constant, these scenarios isolate the effect of turbine size on energy yield, variability, and wake interactions. The comparison also helps bound the range of possible outputs and highlights the benefits of technological scaling. Overall, this approach allows us to analyze the response of large-scale offshore wind power to turbine characteristics while maintaining methodological clarity.

**At the least the three points mentioned above should be included in the paper. I repeat again that I really would like to see this paper published, but I also feel that it is necessary to include this to avoid misinterpretation of the results. I am somewhat surprised that the authors are so reluctant to include these relative small changes. I think that we all agree that not the full uncertainty of the model output is assessed, so why not make this limitation more explicit? I strongly believe that mentioning the limitations of a paper helps to progress research in the best possible way. It does not make the work less valid.**

We thank the reviewer for their thoughtful comments. Following our clarification regarding the distinction between uncertainty and sensitivity, we now better understand the reviewer's intentions. We appreciate this perspective, and now that it is clear, we recognize that the suggested points help to improve the manuscript. As shown in the revised version, these comments have been carefully considered, which we believe strengthens the clarity and robustness of our work.

---

### Reply to RC3

**The title ("Uncertainty in Offshore Wind Power Forecasts: A Regional Climate Modeling Approach for the North Sea") is somewhat overstated and a bit misleading; this appears to be part of the misunderstanding expressed by the authors in their response with version 2.**

**An industrial-grade uncertainty analysis, i.e., uncertainty quantification of wind resource as done by wind engineers (at least in the current decade, typical for current WES readership) is not undertaken here. Instead a sort of ensemble variability is found, based on choosing 2 different regional/global forcing fields (ERA5 & ERA-I, though over different time periods), 3 different turbine types/mixes with corresponding hub heights, and 2 different Fitch-TKE coefficients. As the previous reviewers mentioned, such a set of choices ignores other significant uncertainty components and driving contributions (further, the IEA 15MW reference turbine is not necessarily representative of those being used until 2030). Additionally, the authors work is not focused on "forecasts".**

**Thus this reviewer suggests a title more like: "Variability of future wind power estimates in the North Sea, through an ensemble of regional climate model forcings and parameterizations".**

The manuscript has been revised to explicitly clarify the specific sources of uncertainty addressed in this study.

The revised title now reads:

“Uncertainty in North Sea Offshore Wind Power: Contributions of Reanalysis Forcing, Turbine Type, and Wake Parameterization”

In addition, the abstract has been modified to better frame the scope of the analysis. Line 6 now reads:

“... However, the associated uncertainties are often only partially addressed due to the complexity and diversity of contributing factors, ranging from technical aspects such as turbine geometry and layout to atmospheric processes across multiple scales, from small-scale turbulence to mesoscale dynamics. ...”

**Relevant articles in wind energy UQ (e.g. Lee & Fields 2021, perhaps even Kelly 2025) are missing. More specifically, so are uncertainty in offshore resource prediction with NWP\mesoscale models (e.g. Bodini et al.2021 including boundary-condition & parametric uncertainty, and Bodini et al.2023). Further, the draft is lacking context or reference to a conference article by Hahmann et al.(2025) on this very subject in the N.Sea, and importantly missing references to Fischereit et al. which get into variability of mesoscale-parameterized wakes.**

Some of the mentioned citations has been considered and added to the manuscript accordingly.

**The article draft could be more easily understood if it had a "main" table showing the collection of choices (ensemble), in addition to the current tables of different setups. Variabilities should also include quotes\expressions as a percentage of corresponding mean\expected values, in the main text, tables, and conclusions. Also, the capacity factor should probably be highlighted in the conclusions, as its difference is separate from simply prescribing different power due to different turbines. The relevant dimensionless (e.g. %) differences due to different factors (ensemble member choices) need to be made clearer.**

We want to point out that our existing Table 2 was created with the goal to summarize the specification of each experiments in a short manner. In this fashion it shows each of the simulation setups, the reanalysis dataset used as driving conditions and the time windows of each scenarios.

The capacitor factor is now also highlighted in the conclusions

“Upgrading from 3.6 MW to 15 MW turbines substantially increases average load factors and power output, highlighting that turbine size is an important factor for offshore wind power uncertainty in the North Sea, with the observed increase broadly consistent with ranges reported in existing offshore wind farm studies.”

**Some of the R-values in Table 4 are lower than what is acceptable in typical use of such re-analysis data for long-term correction ('LTC') in resource assessment; this should be discussed\explained, as it currently casts some doubt on the validity of results.**

We added to Section 4.1 “Wind speed validation” the following explanation:

“The correlation between time series from an observational station and model data can be

explained by their spatial representation. Observational stations measure a single point, which is subject to high local variability. In contrast, a model grid box represents the average wind speed over an area of approximately 4 km<sup>2</sup>. This spatial averaging smooths out local fluctuations, leading to lower correlations with point measurements.”

**More comments and suggested edits are included in the attached annotated PDF-file. An example is also given below.**

**I. 424: quantify (e.g. with X% bias and Y% RMSE), instead of using "accurately" as an oversimplification or potential overstatement.**

We sincerely appreciate the reviewer's time and expertise; their detailed comments were instrumental in strengthening our analysis.