Netherlands Enterprise Agency

Q&A Webinar HKW Wind Resource Assessment

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Questions: from the audience
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1. **Question***: It strikes me as a missed opportunity if you had 3 floating Lidar buoys at the site that you could have deployed 1 at the far end of the site to better inform a validation of wind speed variation across the site; was that considered? Having one co-located to the main FL would have been sufficient for redundancy.*
   Answer: The primary focus of the measurement campaign is to deliver a high quality time series suitable for wind resource analysis and energy yield calculations. As such the focus is in ensuring that the current measurement location has an as high as possible data recovery rate. The chosen locations are based on a data need to help clarify the metocean conditions on site as there is a seabed ridge in between HKWA and HKWB/C. However, it is recognised that an extension of the use-case to look at wind speed gradient might be of value and this will be examined as and when confidence in year 2 campaign data recovery is confirmed. Additionally, the Dutch North sea area is subject to a number of studies based on numerical models (DOWA, ERA5, NEWA, HARMONY etc) and fixed point offshore measurements (K13, LEG, EPL etc). All of the studies to date support the HKW reported wind speed gradient.

2. **Question**: *What is driving your decision to take 1999 as the consistent start date of your long term reference (ERA5)? Is this just to obtain a 20 year reference period?*
   Answer: According to the literature (e.g. Liléo, E. Berge, O. Undheim, R. Klinkert, R. E. Bredesen, Long-term correction of wind measurements. State-of-the-art, guidelines and future work, Elforsk report, 2013), using 15 or 20 years to represent best the conditions over the lifetime of the wind farms leads to the lowest uncertainties. Selecting between 15 or 20 years is more a preference where we select 20 years. To align the wind climate with the metocean desk study, we have selected the end period to be the end of 2019 and counting back 20 years leads to the selected measurement period.

3. **Question**: *What height interval has the wind shear alpha exponent been calculated over?*
   Answer: The wind shear at the buoy locations was derived using heights of 80, 100 and 120m; refer to the "Wind shear calculation" section of the report when available.

4. **Question**: *A measurement uncertainty of ~2.5% for the floating Lidar seems quite low; good to hear that the latest OWA guidance has been followed. What assumption has been made for classification uncertainty?*
   Can you say some words on the instrument uncertainty of the HKW lidars used compared to BWFZ, HKZ and HKN lidars?
   Answer: The current uncertainty level is based on previous studies released by RVO and the uncertainty formulation presented by DNV GL for WS188 and WS187 systems based on the pre-deployment verification test. The formulation of uncertainty for RSD and FLS devices is still, we feel, open to some interpretation as to when some elements can be treated as bias, and therefore calibrated out, and where there is an uncertainty relating to the measurement capability. The current formulation is based on the evidence for these two systems, but the user of the data should have sufficient detail within the report to undertake their own uncertainty analysis

according to their internal practices. For further reading we recommend The Carbon Trust document : Lidar uncertainty standard review methodology review and recommendations.

5. **Question**: *What is the average turbine spacing or power density is resulting from the assumed layouts derived?*
   Answer: The coordinates for the 2 indicative layouts will be provided in the report. Wind farm layouts provided here were optimized maximizing energy yield. The minimum distance between the individual turbines was set to 6 times the rotor diameter in the dominant wind direction and 4.5 times perpendicular to the dominant wind direction. The optimisation was performed taking into account the following parameters: the wind resource (resolution of 100 m), random pattern for the layout and estimated wake effects. Based on these parameters, the algorithm will attempt to find the layout with maximum energy yield (including wake effects). Note that this is however a preliminary assessment and it is recommended for the reader to evaluate layout implantation by themselves, as the main focus of this report remains wind resource assessment and not energy yield.

6. **Question**: *Have you applied a confidence weighting to each wake model when calculating the average?*
   Answer: No, a simple averaging was used in this case as we believe all models are associated with the same level of (un)certainty. The part of the assignment on wake modelling is added mainly to identify the attention points when performing wake assessments for the zone. It is recommended for the reader to further investigate wake modelling by their own means.

7. **Question**: *Will RVO take the conclusions about the potential external wake losses when specifying which external wind farms to be modelled in the bid compliant energy yield report as part of the tender next year?*
   Answer: This has not been decided yet. The HKWWFZ permit tender regulation, which is scheduled to be published in the course of 2021, will provide this information.

8. **Question**: *Has been a nested mesoscale/CFD model been considered and/or performed?*
   Answer: No, given the scale of the gradient at stake mesoscale modelling appeared sufficient. The validation process and results are as well extensively discussed in the report and show that all the tested models, currently available, already perform well.

9. **Question**: *Have you considered other sources for stability? How much do you trust ERA5 in general? Shouldn't be validated with other sources?*
   Answer: No, ERA was the only source used here. Values of stability from ERA5 data were mainly used to bin data into three categories (unstable/neural/stable). To confirm the use of ERA5 to estimate the stability conditions at HKWWFZ, we have made a comparison between ERA5 and the shear/TI measurements of Ijmuiden as there is a strong link with stability and shear/TI. This comparison gave us enough comfort to use ERA5. A comparison with other models could be performed but would have lead us to far, as assessing the stability conditions at the site was no specific requirement of the assignment and will always be based on assumptions/models due to the lack of more environmental measurements.

10. **Question**: *On what basis did you associate TI and wake decay constant?*
    Answer: TI and wake decay constants (WDC) were associated based on the formula: WDC = 0.8 x TI. This was only the case for the stability weighted model based on Park 2. Standard Park 1 and Park 2 wake computations were used with standard parameters, using wake decay constants of respectively 0.038 and 0.06.

11. **Question**: *The delta of wakes between internal and external+blockage is significant. How much is the external wakes and how much the blockage?*
Wake loss (internal) from 9% to 18% (internal + external +blockage) looks scary. Any further explanation ?
Answer: Blockage accounted for 2.3% of losses for both wind farm configurations that were investigated. External losses accounted for about 7% of the losses. The latter figure is indeed high compared to industry standards. This is due to an extensive list of existing future wind farms taken into consideration for the assessment (see the report for details), as well as to a wake model taking into account long-distance wakes which is not the case of most industry-standard codes, but in line with satellite measurements which have showed that large-distance impacts are expected under certain conditions. Our report highlights that wake losses are uncertain, as shown by the range of outputs from different wake models, but did not delve any further into this issue given its main focus on wind resource assessment. Indeed, this wake assessment merely meant to highlight that the impact of blockage as well as of the numerous neighbouring wind farms planned at a large distances from HKW are expected to be the most difficult to assess. Therefore, given uncertainties on wake losses it is recommended for the reader to further investigate wake modelling by their own means.

12. **Question**: *Could you elaborate a little more on how the wind farm layouts are optimized? Is it based on wake loss minimization or energy yield maximisation?*
Answer: The coordinates for the 2 indicative layouts will be provided in the report. Wind farm layouts provided here were optimized maximizing energy yield. The minimum distance between the individual turbines was set to 6 times the rotor diameter in the dominant wind direction and 4.5 times perpendicular to the dominant wind direction. The optimisation was performed taking into account the following parameters: the wind resource (resolution of 100 m), random pattern for the layout and estimated wake effects. Based on these parameters, the algorithm will attempt to find the layout with maximum energy yield (including wake effects). Note that this is however a preliminary assessment and it is recommended for the reader to evaluate layout implantation by themselves, as the main focus of this report remains wind resource assessment and not energy yield.

13. **Question**: *Do you see any opportunity for in the future to decrease the uncertainties you mentioned?*
On the short term and specifically for this assessment, using the full set of 24 months of data for the HKW LiDAR campaign could potentially reduce the long-term correction uncertainty (if data-quality of the additional 12 months is sufficient). On a longer term, further work on wind LiDAR uncertainties where LiDAR uncertainty is better defined in standards such as IEC, could possibly reduce uncertainties provided here. As for uncertainties on blockage and wake modelling they should decrease as research progresses and eventually computational power increases.

14. **Question**: *Looking at the 100 m mean wind speed central estimate and its associated uncertainty, the p10 value is about 10.1 m/s, and the p90 is about 9.3 m/s. In reality, one would expect the mean wind speed at this site to be in between the values at IJmuiden and OWEZ/HKZ/HKN. Therefore, this uncertainty seems a bit large, what do you think?*
Answer: Long-term wind speed at HKW is indeed predicted to be larger than long-term wind speed at OWEZ and lower than long-term wind speed at Ijmuiden, as expected given the horizontal wind speed gradient measured/modelled between offshore locations and the coast. However the uncertainty on long-term wind speed depends on multiple factors, including climate variability/inter-annual variability which affects the uncertainty at HKW as well as at Ijmuiden and OWEZ locations. Therefore the P90 at HKW should be compared to the P90 at OWEZ and Ijmuiden, rather than to the P50 at these locations.

15. **Question**: *which value of the "k" (the weibull shape parameter) has been used to fit the wind data to the graph shown on the earlier slide?*
    Answer: At HKW Lidar location, for the short-term data we have a value of 2.20, and for the long-term data:2.29. These details will be provided in the report.

16. **Question**: *was there any validation of the wind direction distribution?*
    Answer: Indeed, as presented in the slides and in the report, wind flow models were validated based on their performance at predicting average wind speed and wind direction as well as performance on the energy rose. These parameters should have helped selecting a model which best represents "measured" time series for their use.

17. **Question**:
    Has long term KNMI data not been considered?
    Answer: For long-term correction we indeed selected one KNMI dataset for our benchmark analysis: our analysis identified Lichteiland Goeree data as the best KNMI source amongst available the various KNMI sources. The performance of this dataset was however found to underperform compared to ERA5 and was therefore not used for long-term correction.

18. **Question**: *how are short-term wind speeds (measured) translated to long term predictions ? What factors are considered in this ?*
    Answer: This was done through a standard MCP (Measure-Correlate-Predict) procedure involving comparisons of several long-term sources and of several MCP methodologies, as detailed in the presentation and in the report. To select the most suitable approach and reference data set, we have identified a few KPI's (correlation, diurnal/monthly profile fit). This analysis has showed that the Neural Network approach combined with ERA5 as reference data was the most suitable.

19. **Question**: *welke onzekerheid is acceptable [what uncertainty is acceptable]*
    Answer: From a wind engineering perspective an uncertainty of 3.24% on a long-term offshore wind speed is a relatively low uncertainty. The previous similar studies had a slightly higher uncertainty where most of the deviation comes from the recent work done on the instrumentation uncertainty on (floating) Lidar's (see Question 20).

20. **Question**: *Hoe veel correctie volgt door het vergelijken en extraheren van gegevens? [how much correction results from the comparison and the*
    Answer*:* About 3 to 4% of the HKW LiDARs data was filtered out. The merging of the datasets from the 3 buoys made it possible for an availability of close to 95% to be reached.

21. **Question**: *How come the uncertainty for representativity is at 1 % for the on-site measurements while Ijmuiden, which is further away, has a lower uncertainty?*
    Answer: The value of "representativeness" used here is linked to long-term resource uncertainty, not to horizontal extrapolation. This said measurements at Ijmuiden are indeed found to be slightly less uncertain than on-site measurements due to a number of factors (fixed met mast vs. floating LiDAR, longer dataset available at Ijmiuden, low uncertainty on horizontal extrapolation).

22. **Question**: *Why didn't you choose K13 or EPL as the third source of measurements, as they show lower overall uncertainties?*
    Answer: Indeed, K13 and EPL show uncertainties as low as OWEZ's. The difference in uncertainty between these sources being small, lower than the uncertainty on these values, an expert view was taken to choose between these sources: the location of OWEZ, directly opposite of Ijmuiden compared to the site location with locations representative of the wind speed gradient from coast to offshore, seemed more balanced compared to other sources that were located further offshore for K13 and further South-West for EPL.