Energy yield prediction of offshore wind farm clusters at the EERA-DTOC European project

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Abstract

A new integrated design tool for optimization of offshore wind farm clusters is under development in the European Energy Research Alliance – Design Tools for Offshore wind farm Cluster project (EERA DTOC). The project builds on already established design tools from the project partners and possibly third-party models. Wake models have been benchmarked on the Horns Rev-1 and, currently, on the Lillgrund wind farm test cases. Dedicated experiments from 'BARD Offshore 1' wind farm will using scanning lidars will produce new data for the validation of wake models. Furthermore, the project includes power plant interconnection and energy yield models all interrelated with a simplified cost model for the evaluation of layout scenarios. The overall aim is to produce an efficient, easy to use and flexible tool - to facilitate the optimized design of individual and clusters of offshore wind farms. A demonstration phase at the end of the project will assess the value of the integrated design tool with the help of potential end-users from industry.

In order to provide an accurate value of the expected net energy yield, the offshore wind resource assessment process has been reviewed as well as the sources of uncertainty associated to each step.

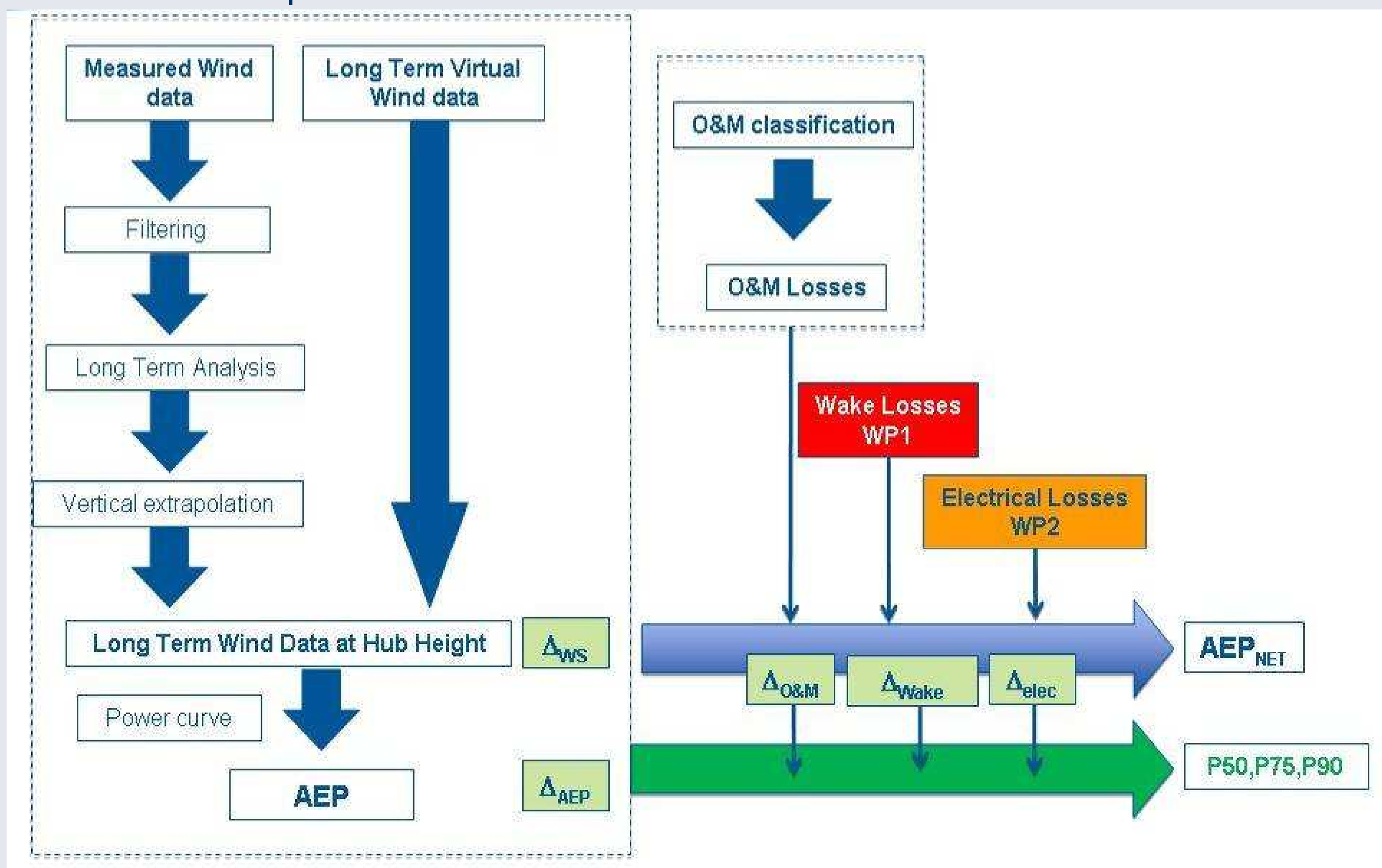
Methodologies for the assessment of offshore gross annual energy production are analyzed based on the Fino 1 test case. Measured data and virtual data from Numerical Weather Prediction models have been used to calculate long term mean wind speed, vertical wind profile and gross energy yield.

Objectives

The main objective of this work is to check methodologies and techniques used in the assessment of the Net Annual Energy Production of offshore wind farms and the associated uncertainties. Given the lack of available data from operational wind farms it is challenging to validate the proposed methodologies, especially regarding uncertainty quantification which is very case-specific.

Methods

In order to provide an accurate value of the expected net energy yield, the offshore wind resource assessment process has been reviewed as well as the sources of uncertainty associated to each step.



Based on FINO 1 input data several institutes and companies have estimated the Gross Annual Energy production using own methodologies. To analyze the different techniques in a homogeneous way, the next information has been requested to each participant:

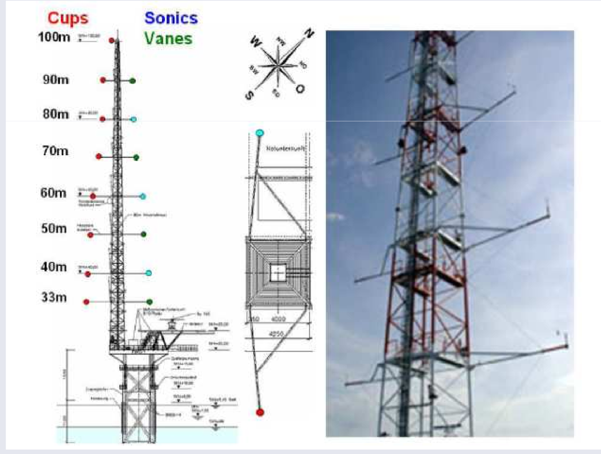
1. For each measured level the mean wind speed before filtering
2. Mean measured wind conditions after filtering for the 100 meters level.
3. Long term wind speed distribution as a function of wind direction sector at 100 m level. Long term reference data is not provided as an input such that each participant can use own reference information (meteorological station or virtual data from databases like MERRA, GFS, World Wind Atlas Data…); this will allow assessing the impact from different reference data sources and Measure-Correlate-Predict (MCP) methods of temporal extrapolation.
4. Mean wind speed at hub height (120 meters).
5. Long-term prediction of gross energy yield in GWh/year, before wake effects and any other losses.
6. The estimated uncertainty of the long term 10-year equivalent predicted gross AEP, including a breakdown of the individual uncertainty components that have been estimated or assumed.
7. Details of how the particular methodology of each participant, in particular on how the wind speed prediction has been carried out (e.g. MCP technique), if measured or modeled wind shear was used, etc.

To analyze the NWP outputs as offshore virtual masts the gross annual energy production has been calculated based on data from nearest grid point of Skiron mesoscale model simulations.

Results

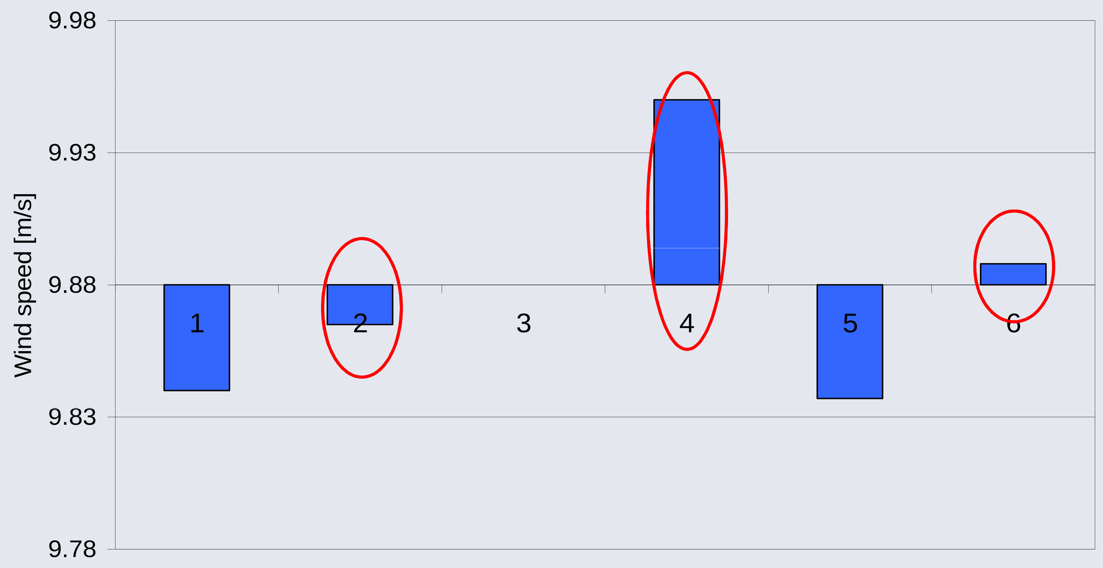
FINO 1 research platform, which is situated in the North Sea has been used as test case for estimating Gross Energy in a hypothetical wind farm.

Ten minutes time series of controlled measured mean, standard deviation and maximum wind speed, mean and standard deviation of wind direction, temperature and pressure from 13/01/2005 to 01/07/2012 and a generic power and thrust curves have been provided as input.



According to the steps analyzed in the FINO 1 Gross energy estimation some critical points have been detected:

1.Filtering: the large deviations in the data recovery after filtering, mainly due to the mast shadowing effect show the need to have clear rules to filtered erroneous data specially in the case of mast shadowing influence. The data quality checking should be for all the measure period available and after this with all the relevant information select the full year analysis period.



Mean wind speed after filtering at 100 m obtained as mean of ten minutes value. Mean value ± 1.0%. Red circles indicates that mast shadow effect has been filtered

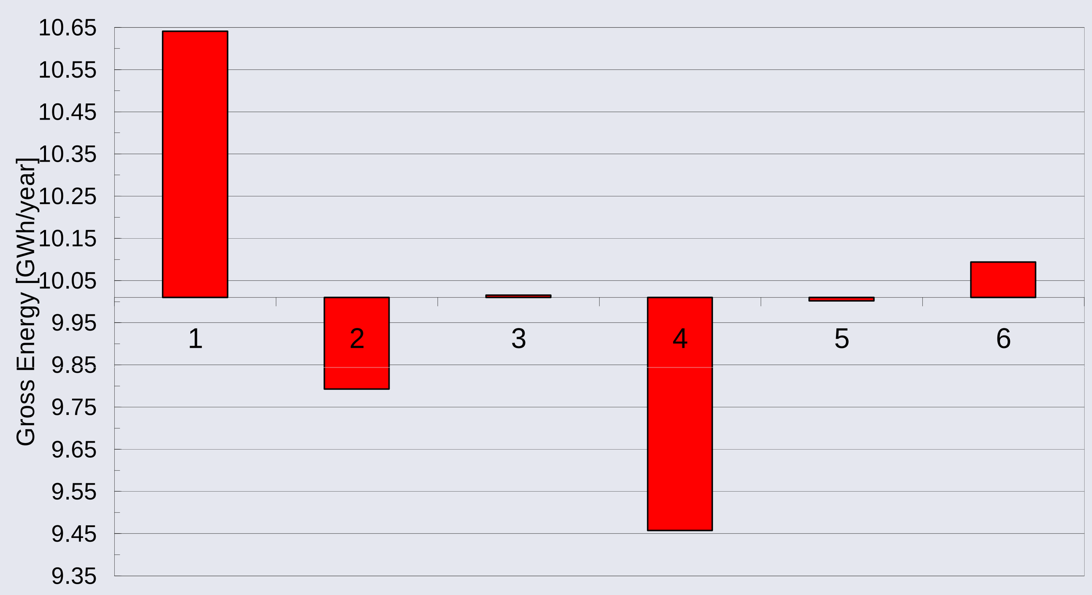
2.Long term: a great variety of reference data and long term correlation methods are used, in each case and depending on the quality of the available data a exhaustive long term analysis should be done including validation and uncertainty assessment.

Participant	Long term period	Long term method
1	From Jan 2005 to Dec 2011	No long term correction
2	From Jan 1983 to Dec 2012	Long-term correction based on monthly NCAR data.
3	From Jan 1996 to Jun 2012	Long-term correction based hourly MERRA data as the reference source. A matrix correlation method was used.
4	From Jan 1979 to Dec 2011	Long-term correction based on monthly reanalysis data. The MCP method was applied for 12 different directional sectors.
5	From Jun 2005 to May 2012	No reference.
6	From Jan 1981 to Dec 2012	Long-term correction based hourly MERRA data as the reference source. A lineal correlation method was used.

Long term mean wind speed at 100 m obtained from frequency distribution of hours in the year as a function of wind speed and direction. Mean value ± 1.5%

3.Vertical extrapolation: everybody has used the Hellmann exponential law that has good results for annual mean values but no when profiles are classified in terms of the observed atmospheric stability and, where the wind shear is overestimated during unstable conditions and underestimated in stable conditions. Stability and how it could be applied for wind resource assessment estimation should be analyzed.

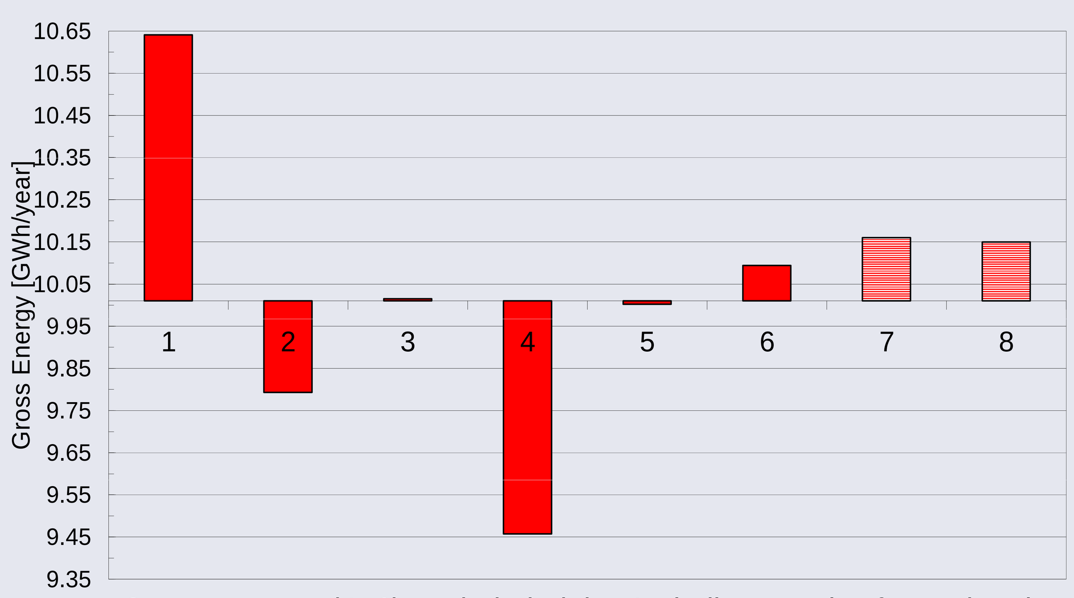
4. Gross Energy: the deviations in the methodologies applied in before steps increasing in the gross energy estimation. According to the results new methodologies, should be explored and traditional methodologies should be checked to avoid big discrepancies like in the case of team 1 who with a similar wind speed distribution and the same power curve has obtained higher gross energy than the others participants.



Gross Energy (P50) at hub height. Mean value ± 6.5%

5.Uncertainty: the sources of the uncertainty are clear but they are not enough to estimate it

6.Virtual masts: the results obtained for Skiron outputs for the FINO 1 site are very good, but more sites to validate are need to conclude that virtual masts are a alternative for initial offshore wind resource assessment.



Gross Energy (P50) at hub height. Including results from virtual data, cases 7 and 8. Mean value ± 6.5%

Conclusions

The FINO 1 test case demonstrate the need of clear and common methodologies and standards to do the wind energy yield assessment in offshore wind farms.

New methodologies should be explored and incorporate to the wind energy yield assessment, like the analysis of atmospheric stability to define the wind profile or the NWP outputs as source of information to estimate the offshore wind resource.

To develop and validate methodologies and procedures wind farm data are need.

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