

Document title: *Thor Offshore Wind Farm - Delivery of data and reports*
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Regarding: *Providing a description of the data, metadata, and reports provided to Energinet by C2Wind, DNV-GL, DHI, and Vortex as part of the Thor Offshore Wind Farm MetOcean Preliminary investigations.*
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Summary of Changes

Revision	Section	Changes
1	All	Initial revision issued for the Client.

Table of Contents

1.	INTRODUCTION	2
2.	DELIVERABLES	3
2.1	DELIVERABLE 1A: WIND MEASUREMENTS	4
2.2	DELIVERABLE 1B: MESOSCALE MODEL DATA	4
2.3	DELIVERABLE 2A: WIND AND OTHER ATMOSPHERIC PARAMETERS	5
2.4	DELIVERABLE 2B: MARINE PARAMETERS AND THEIR CORRELATIONS WITH THE WIND	5
2.5	ADDITIONAL DELIVERABLE: DNV-GL CERTIFICATION REPORT – CONCEPT, AND STATEMENT OF FEASIBILITY	6
3.	ERRATA	7
4.	REFERENCES	8

1. Introduction

In connection with the Thor Offshore Wind Farm (Thor OWF) tender, C2Wind has supported Energinet with procuring, producing, quality-checking, and supplying technical information related to site conditions. This work has been focusing on two main activities that may be carried out by wind farm developers as part of their background analysis for a tender submission:

- 1) Wind Resource Assessment (WRA): the study and characterisation of wind conditions for performing Energy Yield Assessments (EYA);
- 2) Site Condition Assessment, apart from both soil and electrical power network conditions: the study and characterisation of wind-, marine-, and other atmospheric conditions for performing Rotor Nacelle Assembly (RNA) site suitability studies and Wind Turbine Generator (WTG) support structures design studies.

On the 13th of May 2019 in Copenhagen, as part of the Thor OWF tender preparation (Technical Dialogue), Energinet and C2Wind presented two options for providing the potential bidders with technical information about the site conditions at the Thor OWF, see Slide 3 of [MOI]: a Default Scope, and a Comprehensive Scope. The Default Scope has subsequently been chosen by Energinet, based on the dialogue with the tenderers which followed the presentation.

As per medio March 2021, this Default Scope information has been gathered, and the present document now aims at providing the pre-qualified bidders with an exhaustive overview of:

- The datasets and reports which form the basis of the Default Scope;
- Additional deliverables, for example the [DNVREPORT] briefly mentioned on Slide 3 of [MOI].

C2Wind wishes to thank Energinet, DNV-GL (now DNV), DHI, DTU Wind Energy, and Vortex for their excellent work and datasets, as well as their collaborative spirits during the course of this project.

2. Deliverables

The list of deliverables delivered by DNV-GL, DHI, DTU Wind Energy, C2Wind, and Vortex – all via Energinet – are provided in Table 2-1. Each item is described in greater detail in the following subsections. The data and reports can be found on Energinet’s FTP server; see Energinet’s Thor OWF website¹.

Deliverable	Reference in [MOI]	Delivered (yes/no)
Deliverable 1a: Wind Measurements		
M2 met mast	Slides 7 and 8	Yes
Høvsøre met mast	Slides 7 and 8	Yes
AKROCEAN Floating LiDAR System	Additional deliverable	Yes
Deliverable 1b: Mesoscale model data		
Vortex SERIES 20 years ERA5 (x3), [VORTEXDATA].	Slides 7 and 9	Yes
Model and data description, [VORTEXREPORT].	Slides 7 and 9	Yes
Deliverable 2a: Wind and other atmospheric parameters		
C2Wind doc. no. 19009-4-2, [WLSCA].	Slides 10 to 12	Yes
C2Wind doc. no. 19009-3-1, [MEAS].	Additional deliverable	Yes
Deliverable 2b: Marine parameters and their correlations with the wind		
DHI doc. no. 11824164 Final 2.0 [DHIREPORT]	Slides 13 to 15	Yes
DHI hindcast data, [DHIDATA].	Slides 13 to 15	Yes
Additional deliverable: DNV-GL Certification Report – Concept, and Statement of Feasibility		
DNV-GL Certification Report and Statement of Feasibility, [DNVREPORT].	Additional deliverable	Yes

Table 2-1: List of the information provided to the bidders as part of the Default Scope described on Slide 3 of [MOI].

¹ See <https://ens.dk/en/our-responsibilities/wind-power/ongoing-offshore-wind-tenders/thor-offshore-wind-farm/preliminary>.

2.1 Deliverable 1a: Wind Measurements

As per Slide 8 of [MOI], measurement data from the Høvsøre- and M2 meteorological masts (met masts), have been made available on Energinet's FTP server. For each dataset, the data and metadata are provided in separate folders, see Figure 2-1. As to the AKROCEAN Floating LiDAR data; both time series and documentation reports have already been made available on Energinet's FTP server. A high-level description these datasets is provided in [MEAS], which is an additional deliverable to the Default Scope; see Section 2.3.

The main reason for providing the bidders with the met mast data for WRA purposes is to help reduce the uncertainty on the long-term wind speed and -direction distribution at the site.

In contrast, it will be the winning bidder's responsibility to eventually make a Site Conditions Assessment for the site, and obtain a conformity statement according to IECRE OD-502:2018, which is relevant for the project through its reference by the Executive Order: [BEK nr 1773 af 30/11/2020](#). In this connection, both the metadata and the document [MEAS] may be helpful for the winning bidder in fulfilling the requirements of Section 7.1.2 of IECRE OD-502:2018; for example the requirements of adequate test methods, appropriate equipment, traceability, etc.

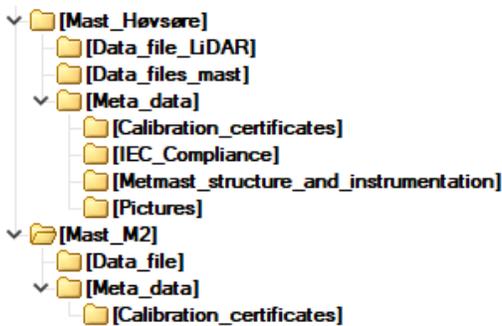


Figure 2-1: Illustration of the Høvsøre- and M2 met mast parts of the data folder structure delivered by C2Wind to Energinet.

2.2 Deliverable 1b: Mesoscale model data

Three datasets have been produced by Vortex, using the Weather Research and Forecasting (WRF) Numerical Weather Prediction system. They consist of wind- and other atmospheric parameter time series at three measurement locations: the Høvsøre- and M2 met masts, and the centroid location of the WINDSEA floating LiDAR system; see [VORTEXDATA].

Besides the time series, Vortex have also delivered the orography and roughness maps used for the production of the time series, see [VORTEXDATA], and a short technical report summarising the model setup; see [VORTEXREPORT].

2.3 Deliverable 2a: Wind and other atmospheric parameters

The information listed on Slides 10 to 12 of [MOI] has been provided in the form of a report containing Wind Conditions for a Light Site Conditions Assessment, see [WLSCA]. This document, and to some extent [MEAS], has been scrutinised by DNV-GL (now DNV) in [DNVREPORT]; see Section 2.5.

Of course, the bidders are free to use other parameters than those in [WLSCA] for the preparation of their bid.

2.4 Deliverable 2b: Marine parameters and their correlations with the wind

The information listed on Slides 13 to 15 of [MOI] is provided in the form of a hindcast dataset, see [DHIDATA], and an accompanying Metocean Hindcast Data and Validation Report, see [DHIREPORT]. [DHIREPORT] has been scrutinised by DNV-GL (now DNV) in [DNVREPORT]; see Section 2.5.

Of course, the bidders are free to use other parameters than those in [DHIREPORT], or elect to use other hindcast datasets than [DHIDATA], for the preparation of their bid.

In connection with the contents of [DHIREPORT], and particularly regarding what it does not contain, it may be helpful to note what is stated regarding the Default Scope on Slides 3 and 4 of [MOI]: The purpose of [DHIREPORT] is not to provide comprehensive and sufficient parameters to the bidders, but instead to provide a basis for the bidders to make their own analysis, as well as provide a few select key parameters (such as extreme H_{m0^-} , H_{max^-} , and C_{max^-} -values). Furthermore, DNV-GL's view on the contents of [DHIREPORT] are provided in [DNVREPORT].

Practically, the contents of [DHIREPORT] were selected through C2Wind's experience with the methods various designers of offshore wind farms use: to help the bidders as much as possible within the Default Scope, while at the same time allowing flexibility for each bidder to use the methods they prefer.

As an example of this, [DHIREPORT] does not include the wave period interval associated with the H_{max^-} -values. The reason for this choice is that there is much variation between how various designers assign these wave period intervals. For instance, some designers tend to use the expressions in Section 6.4.4.1 of IEC 61400-3-1:2019/A11:2020, often accompanied with a suitable justification that it is applicable for the site in question. Other designers select quantiles of a dataset of (H,T) -pairs from individual-wave simulations of storm events, while others again use the guidance of Section A.8.4.1 of ISO 19901-1:2015 (through it being indirectly referenced in Section 6.4.4.1 of IEC 61400-3-1:2019/A11:2020).

Therefore, in recognition of the varied approaches that may be used by the bidders, this item is knowingly left open. Thereby, it is left up to the bidders to establish Extreme Sea State (ESS) associated wave period intervals, particularly for analysing ESS Design Load Cases for Integrated Load Analysis, but also for other purposes, e.g. for assessing wave run-up loads.

Other examples of parameters, for which C2Wind has chosen to leave the selection to the bidders, are:

- C_{max^-} -values (where the results of two commonly used approaches are listed in [DHIREPORT]).
- Extreme Low Still Water Levels.
- Associated Still Water Levels for ESS.
- Local Still Water Level Change due to climate change and Vertical Land Movement (i.e. these are not included in [DHIREPORT]).

2.5 Additional deliverable: DNV-GL Certification Report – Concept, and Statement of Feasibility

As additional deliverables to the default scope, a DNV-GL (now DNV) Certification Report, and an accompanying Statement of Feasibility, are made available. To produce these, DNV-GL have reviewed three documents: [MEAS], [WLSCA], and [DHIREPORT]. This is in accordance with the final bullet point in the Default Scope list on Slide 3 of [MOI].

3. Errata

Table 3-1 provides a list of errata regarding topics discovered after the issuance of the datasets and reports to Energinet and DNV-GL.

Item	Resolution
The headings displayed on the maps in [MEAS] and [WLSCA] are incorrect; they are offset by 5°. For instance, the 270°N heading in Figure 5-7 of [WLSCA] should read 275°N.	Maps with the correct headings have been produced: they are made available as individual image files in the folder \Reports\C2Wind\Maps.

Table 3-1: List of errata discovered after the issuance of the datasets and reports to Energinet and DNV-GL.

4. References

[DHIDATA]	<p>DHI. Wind-, hydrodynamic-, and spectral wave data provided by DHI together with [DHIREPORT]. See details in Sections 1 and 4 of [DHIREPORT]:</p> <p>Wind-, hydrodynamic-, and spectral wave (integral parameters) model data time series at three locations across the Thor Offshore Wind Farm project area, labelled P1, P2, and P3. For each location PX, where $X \in \{1,2,3\}$, the data are provided in a folder labelled PX and consists of 5 ASCII files labelled as follows, where <i>D.DDDD_DD.DDD</i> denotes the geographical longitude- and latitude coordinates, respectively in °E and °N):</p> <ul style="list-style-type: none"> ➤ CREA6_10m_PX_19950101_010000_20181231_230000.csv; ➤ CREA6_100m_PX_19950101_010000_20181231_230000.csv; ➤ Danish_Waters_Water_Level_and_Current_2D_MIKE_21_Hydrodynamic_Model_HD_DHI_D.DDDD_DD.DDD_19950101_010000_20181231_230000.csv; ➤ Danish_Waters_Wave_Parameters_Integrated_MIKE_21_Spectral_Wave_Model_DHI_D.DDDD_DD.DDD_19950101_010000_20181231_230000.csv; ➤ MIKE21_HD_parameters_tide+residual_D.DDDD_DD.DDD_19950101_010000_20181231_000000.csv. <p>A time series of directional wave spectra at one location, labelled <i>DWS</i>. The data are provided a in folder labelled <i>DWS</i>, in the form of binary MATLAB files, with one file for each year $YYYY \in \{1995; 1996, \dots, 2018\}$, with files names of the form:</p> <ul style="list-style-type: none"> ➤ <i>SW_DKW_Domain_Spectra_0.1deg_YYYY_7.70E56.40N.mat</i>.
[DHIREPORT]	<p>DHI. Thor Offshore Wind Farm. Metocean Hindcast Data and Validation Report. Project no. 11824164. Revision Final 2.0 (2020-11-19).</p>
[DNVREPORT]	<p>DNV-GL. Thor Offshore Wind Farm – Certification Report – Concept. Doc. no. CR-C-DNVGL-SE-0190-07164-0. Revision 0 (2021-02-26).</p> <p>Accompanying this report is this Statement of Feasibility: DNV-GL. Statement of Feasibility – Issued for: Concept of Thor Offshore Wind Farm – Comprising: Wind Turbines. Statement no. C-DNVGL-SE-0190-07164-0 (2021-02-26).</p>
[MEAS]	<p>C2Wind. Thor Offshore Wind Farm - Description of measurement datasets. Doc no. 19009-3-1 (2020-12-26).</p>
[MOI]	<p>Energinet/C2Wind. Technical Dialogue on Site Investigations – MetOcean. Doc. no. 19009-1. Revision 3 (2019-05-11). Link: https://ens.dk/sites/ens.dk/files/Vindenergi/3_metocean_input.pdf</p>

[VORTEXDATA]	<p>Vortex Factoria de Càlculs SL. Weather Research and Forecasting (WRF) Numerical Weather Prediction System time series, downscaled using the ERA5 reanalysis dataset as input. The time series have been computed at three measurement locations:</p> <ul style="list-style-type: none"> ➤ The Høvsøre met mast. ➤ The M2 met mast. ➤ The centroid of the WINDSEA3 floating LiDAR system in the Thor Offshore Wind Farm project area. <p>The time series are delivered as netCDF files (produced by Vortex), and as ASCII files (exported by C2Wind from the Vortex web interface).</p> <p>For each of these datasets, the orography (in meters above mean sea level) and roughness (aerodynamic roughness length in centimetres) maps used as input to WRF are provided as ASCII files (with the extension <i>.asc</i>).</p>
[VORTEXREPORT]	<p>Vortex Factoria de Càlculs SL. Vortex WRF Model Configuration: SERIES. Filename: <i>Vortex.config.Series.pdf</i>.</p>
[WLCSA]	<p>C2Wind. Thor Offshore Wind Farm - Wind Conditions for a Light Site Conditions Assessment. Doc. no. 19009-4-2 (2021-01-29).</p>