TECHNICAL DIALOGUE ON SITE INVESTIGATIONS

MetOcean

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CONTENTS

Dialogue Questions:

Through the presentation, suggestions for dialogue questions will be written in text boxes like this. They are intended to guide the dialogue, but you are of course welcome to not answer them, and to ask any questions of you own.

METOCEAN – OVERALL STRATEGY

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Two main options will be presented in the following slides:

1. Default Scope (default option)
   - Energinet will provide metocean data and -documentation which is sufficient for the bidders to submit a qualified economic bid.
   - This material shall have uncertainties so small that they only have a minor effect on the bid. Furthermore, it shall be so extensive that it, for this purpose, either directly provides the bidders with the necessary MetOcean parameters, or allow the bidders and their advisors to calculate these parameters themselves.
   - This material shall be as detailed, and of a quality at least as good, as what is used elsewhere in Northern European offshore wind projects for this purpose.
   - No certification of the material; only plausibility statements from an independent (possibly DS/EN 61400-22 accredited) third party.

2. Comprehensive Scope (only provided if bidders present convincing arguments for it)
   - In addition to the Default Scope:
     - The material provided will either directly state, or be applicable as a basis to calculate, Site Conditions Assessment (SCA) parameters for MetOcean topics according to the SCA module of DS/EN 61400-22, and, by reference, IEC 61400-3-1 (2019).
     - The SCA MetOcean parameters directly stated will be certified* by an accredited Certifying Body according to IEC 61400-3-1 (2019).
     - Where SCA MetOcean parameters are not directly stated, the material applicable as a basis to calculate these will – to the extent possible – be verified by an accredited Certifying Body according to IEC 61400-3-1 (2019).

*: Here, and in the remainder of the presentation, the concept of "certified" parameters will be used in the colloquial meaning that a Certifying Body accredited to certify according to DS/EN 61400-22 has verified the parameters according to IEC 61400-3-1 (2019), and have accepted the values in this context, through some statement (e.g. a comment sheet or certification report). In contrast, DS/EN 61400-22 does not formally speak of certification of SCA parameters in the context of Project Certification, but only of modules, such as the SCA module, through issue of Conformity Statements.

METOCEAN – OVERALL STRATEGY

ENERGINET

Notes regarding the Scopes:

1. Default Scope (default option)

   - This is intended to provide sufficient information to:
     - ✓ Allow the bidders to make a detailed Wind Resource Assessment and, with their Wind Turbine Generator (WTG) type and wind farm layout, a production estimate).
     - ✓ Allow the bidders to make preliminary structural design.
     - ✓ Provide hindcast data time series for installation and Operations & Maintenance (O&M) planning, e.g. weather window analysis.

       SCA-parameters (for structural design) are uncertified and may change later.

       The bid winner may need to have sufficient time in their time schedule for producing a local hindcast model (ca. 4-6 months + time for supplier selection) and, using this, making of an SCA (additional ca. 2 months), as well as certification of these (additional ca. 2-3 months). Alternatively, the time schedule may contain a design risk (i.e. the design may change due to changes in design values during the certification process).

2. Comprehensive Scope (only provided if bidders put forward convincing arguments for it)

   - In addition to the contents of the above Default Scope:
     - ✓ Will provide a local hindcast model dataset and report, as well as an accredited Certification Body verification of it according to IEC 61400-3-1 (2019). This will eliminate ca. 5-7 months from the design time schedule (time for hindcast model & reduce certification time), as well as removing minor uncertainties in installation- and O&M planning through a more accurate hindcast dataset.
     - ✓ Will provide a part of the certified SCA parameters (more on this on later slides).

       Some SCA parameters will have to be assessed by the bidder, who will also have to obtain certification for these (more on this on later slides).

Dialogue Question M1:
Please state your overall preference for Options 1 or 2, and outline the impact each would have on your bid (each item is treated in detail in the following slides).

METOCEAN – CATEGORIES

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The topic of MetOcean conditions will be split into the following categories and subcategories:

1. Wind Resource Assessment (WRA).
   a. Wind measurements.
   b. Mesoscale modelling.

2. Site Conditions Assessment (SCA) according to IEC 61400-3-1 (2019)
   a. Wind- and other atmospheric parameters.
   b. Marine parameters and their correlations with the wind.
   c. Other SCA parameters (lightning, tsunamis, earthquakes, solar radiation, and icing on blades).

- For all topics, the vertical reference will be the local Mean Sea Level (MSL), which is close to the zero-elevation of the Danish Vertical Reference 1990 (DVR90).

- An overview of relevant measurement data is given on the next slide.
  - After the next slide, we will revert to discussing what data is being considered for each of the subcategories above.

METOCEAN – MEASUREMENT DATASETS

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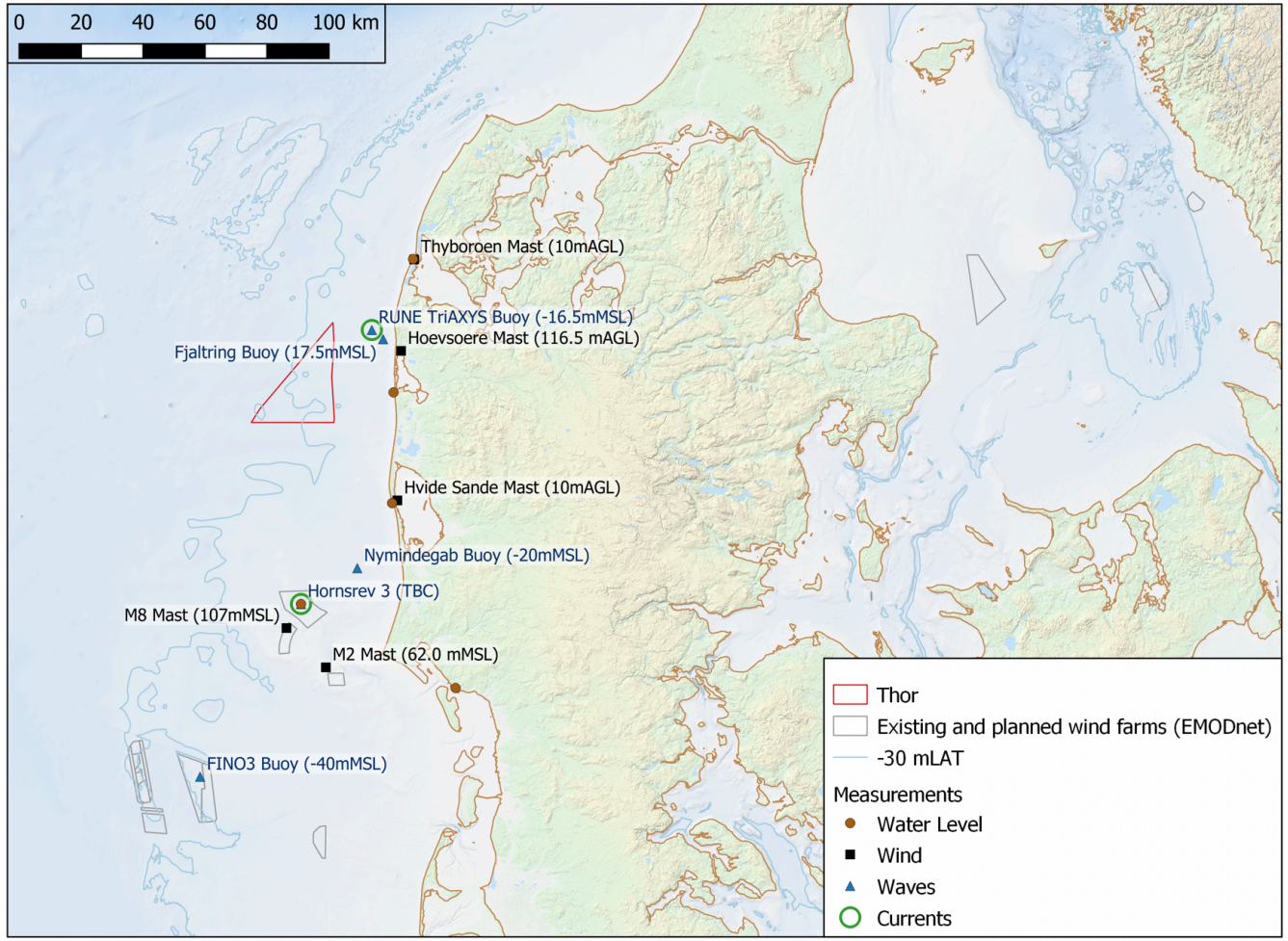
Overview of measurement datasets:

- Energinet is investigating the possibility of obtaining these datasets for use in establishing the MetOcean conditions at the Thor site.
- Later in this presentation, it will be stated for each of the categories (WRA and SCA) what measurement data is relevant.
- Unless otherwise noted in the following slides, it is not the intention to supply the bidders with most of these datasets.
  - Instead, most of the datasets will be used to validate hindcast models, including providing ways to assess their uncertainties.
  - Many of the datasets are publicly available, although not necessarily free of cost, and bidders interested in them are welcome to obtain them.
  - One type of data that will be supplied to the bidders is wind measurements usable for WRA – more on this later.



Dialogue Question M2:

Please point out any additional datasets that you regard as important for the topics of this presentation.

METOCEAN – WRA

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Category 1: Wind Resource Assessment (WRA)

The overall strategy is:

- To provide to the bidders:
  a. Sufficient measurement data to allow accurate WRA at the locations of the measurement equipment.
  b. Data from a single mesoscale model to allow horizontal extrapolation from the measurement equipment locations to the site, as well as give one option for long-term correction.
  c. Accompanying documentation for a. and b.
- That the bidders use this information, supplemented with their own choice of analysis methods and datasets for long-term correction, to calculate the wind resource for the Thor site.
- That the bidders use this wind resource, along with their choice of WTG type, hub height, and wind farm layout, to arrive at their energy production estimate.

Please note: This means that a WRA is not intended to be delivered to the bidders.

Dialogue Question M3:
Do you see this as a suitable approach, or would you prefer that a Wind Resource Assessment is provided to you?

METOCEAN – MEASUREMENTS FOR WRA

ENERGINET

Category 1a: WRA – Wind measurements

- In addition to measurements of wind speed and –direction, measurements of air- and water temperature and air pressure are also planned to be made available to the bidders.

Name	Location	Duration (10-min statistics)	Dataset made available to bidders?	Notes
FINO3	See map	Ca. 10 years (2009 to now)	No, but publicly available (at a cost of the order of 1500 €)	Data access can purchased from BSH here: http://fino.bsh.de/index.cgi Information on the mast here: https://www.fino3.de/en/
HR2 LiDAR	Horns Rev 2 OWF Accommodation Platform	Several years	No, not expected.	This dataset was made available to the bidders for Horns Rev 3 OWF only. The LiDAR's location means that it is often in the wake of the HR2 OWF, on its eastern side, and the LiDAR data are therefore not straightforward to use for WRA.
Høvsøre Mast	Testcenter Høvsøre	Ca. 15 years (2004 to now)	Yes, expected to be made available	Publicly available at this time, although not free of cost. An overview of the mast location and instrumentation can be found here: http://orbit.dtu.dk/files/116780860/Ten_Years_of_Boundary_Layer.pdf An online data preview can be found here: http://rodeo.dtu.dk/rodeo/GraphicsPage.aspx?&Project=157
M2	Horns Rev OWF	Ca. 5 years (1999-12 to ca. 2004)	Yes, expected to be made available.	This dataset was made publicly available, at no cost, during the tender for Horns Rev 3 OWF, along with documents on how to correct miscalibrations of some of its signals. This dataset, and the documents, are expected to be made available to the bidders.
M8	Horns Rev 2 OWF	Several years	No, not expected.	This dataset was made available to the bidders for Horns Rev 3 OWF only. M8 is located inside the operating HR2 OWF, and its wind data are therefore difficult to use for WRA.

Dialogue Question M4:

Are the measurement datasets, which are planned to be made available, suitable for you, and could any of them be left out?

METOCEAN – MESOSCALE MODEL FOR WRA

ENERGINET

Category 1b: WRA – Mesoscale model data

- Data from a single mesoscale model will be delivered. This data is intended to allow horizontal extrapolation of the wind resource from the measurement equipment locations and to the Thor site, as well as give one option for long-term correction.
  - The bidders will probably wish to supplement this with their own choice of datasets for long-term correction of the Wind conditions.

- The implementation of the mesoscale model itself will not be provided. Only data usable for horizontal extrapolation, and for long-term correction, will be provided.

METOCEAN – SCA WIND PARAMETERS

ENERGINET

Category 2a: SCA – Wind- and other atmospheric parameters

- The parameters delivered are the ones stated in the tables on the next two slides (Default Scope).
  - As noted above, these will be intended for preliminary structural design according to IEC 61400-3-1 (2019) and, by reference, IEC 61400-1 (2019).
  - An assumed hub height will be ca. 120 mMSL, with instructions of how to extrapolate parameters to other elevations.
  - Only undetailed documentation of the data, the measurement equipment, and the validations will be provided.
  - As noted above, parameters will not be certified, but a plausibility from an independent third party will be provided.
- Not delivered as part of the Default Scope (belong to the Comprehensive Scope):
  - Values that are formally required by IEC 61400-3-1 (2019), but of secondary importance for structural design (such as Relative air humidity, Ambient Air temperature ranges, and Design Air Temperature according to DNVGL-ST-0126).
  - Data- and measurement descriptions and quality checks as required by DS/EN 61400-22.
  - Certification of the SCA Wind- and other atmospheric parameters.
- Not delivered (for both the Default- and the Comprehensive Scope):
  - Wind speed and -direction distribution parameters at hub height that conform with the WRA.
  - WTG-type dependent parameters (such as gust amplitudes, as well as wake- and wind farm turbulence).

Dialogue Question M5: *In addition to the lists on the next two slides, do you need any additional parameters assessed?*
Dialogue Question M6: *If you prefer the Comprehensive Scope over the Default Scope, please state clearly the impact it would have on your bid.*

METOCEAN – SCA WIND PARAMETERS

ENERGINET

Category 2a: SCA – Wind- and other atmospheric parameters

- The following parameters will be provided (continued on the next slide).

Normal conditions parameters	Value/Note
Mean wind speed at an assumed hub height	A value, which is sufficiently accurate for preliminary structural design, but not for energy yield analysis.
Omni-directional Weibull wind speed distribution parameters at an assumed hub height	Values, which are sufficiently accurate for preliminary structural design, but not for energy yield analysis.
Wind profile for wind speed extrapolation with height	$WS(h) = WS_{\mathrm{Ref}} \cdot \left(\frac{h}{h_{\mathrm{Ref}}}\right)^{XYZ}$ Here, h and h_{Ref} are in mMSL.
Wind profile for Integrated Load Analysis, Normal Wind Profile (NWP)	$WS_{\mathrm{NWP}}(h) = WS_{\mathrm{NWP,Ref}} \cdot \left(\frac{h}{h_{\mathrm{Ref}}}\right)^{XYZ}$ Here, h and h_{Ref} are in mSWL.
Normal Turbulence Model (NTM)	A table of Wind Speed-dependent Free Stream Turbulence Intensities, which can be used for preliminary structural design for elevations at, or larger than, an elevation stated here.
Mean air density at an assumed hub height	$\rho_{\mathrm{Ref,N}} = XYZ \ \frac{\mathrm{kg}}{\mathrm{m}^3}$
Mean air temperature at an assumed hub height	$T_{\mathrm{Ref,mean}} = XYZ$ °C
Extreme Turbulence Model (ETM) parameters	**Value/Note**
Extreme Turbulence model (ETM)	A table of Wind speed-dependent ETM Turbulence Intensities, which can be used for preliminary structural design for elevations at, or larger than, an elevation stated here.

METOCEAN – SCA WIND PARAMETERS

ENERGINET

Category 2a: SCA – Wind- and other atmospheric parameters

➢ The following parameters will be provided (continued from the previous slide).

Extreme conditions parameters (Extreme Wind Model, EWM)	Value/Note
Maximum 10-minute mean wind speed for a 50-year EWM at an assumed hub height	A single value, or directionally binned extreme values.
Turbulence Intensity for use with EWM	TI_{EWM} = XYZ %
Wind profile for Integrated Load Analysis	$WS(h) = WS_{\mathrm{Ref}} \cdot \left(\frac{h}{h_{\mathrm{Ref}}}\right)^{XYZ}$ Here, h and h_{Ref} are in mSWL.
Wind profile for extreme wind speed extrapolation with height	$WS(h) = WS_{\mathrm{Ref}} \cdot \left(\frac{h}{h_{\mathrm{Ref}}}\right)^{XYZ}$ Here, h and h_{Ref} are in mMSL.
Mean air density at an assumed hub height	$\rho_{\mathrm{Ref,E}} = XYZ\ \frac{\mathrm{kg}}{\mathrm{m}^3}$
Items that are not delivered	**Value/Note**
Not delivered: Wake- and wind farm turbulence intensities	This is not delivered, since it depends on both WTG type (through its C_T-curve and rotor diameter) and the wind farm layout.
Not delivered: Gust parameters	This is not delivered, since the gust parameters are either determined by the standard to which the WTG type is type certified, or depend on the WTG type (through its C_T-curve and rotor diameter) and the wind farm layout. Furthermore, the way gusts are applied is determined by the standard to which the WTG type is type certified.

METOCEAN – SCA MARINE PARAMETERS

ENERGINET

Category 2b: SCA – Marine parameters and their correlations with the wind

The overall strategy is:

- To provide to the bidders:
  - Hindcast time series for marine parameters across the site, as well as corresponding wind speed and –direction time series, particularly for the part of the site with the most severe wave conditions.
  - A report containing a hindcast model description, validations against measurement data, and extreme value analysis results.
- That the bidders use this information, supplemented with their own choice of analysis methods, to arrive at design parameters according to IEC 61400-3-1 (2019); e.g. metocean parameters for NSS, SSS, and ESS.
  - The reasons for leaving the calculation of design parameters to the bidders are that:
    - The NSS and SSS-parameters depend on the wind speed distribution at hub height, which is left open to the bidders to decide.
    - The substructure- and foundation designers in the market have various preferences for how to structure these analyses, and how their results are used in Integrated Load Analysis and Structural Design.

The details of this strategy are treated in the following slides.

Dialogue Question M7:
Is this approach suitable for you?

METOCEAN – SCA MARINE PARAMETERS

ENERGINET

Category 2b: SCA – Marine parameters and their correlations with the wind

The intended Hindcast time series for marine parameters across the site consist of:

- At least 20 years, but preferably close to 40 years, of hourly sampled hindcast time series of:
  - Wind Speed and –direction at 10 mMSL (and, possibly, at a larger elevation).
  - Depth-averaged current speed and –direction.
  - Still Water Level.
  - Wave integral parameters, at least:
    - H_{m0}, T_p, T_{02}, mean wave direction, and peak wave direction.
    - These integral parameters will be delivered for both the Total Sea State, as well as for Wind-Sea and Swell individually. A standard Wind-Sea/Swell-separation criterion will be used.
  - Directional wave spectrum.
- For the Default Scope: Using a regional hindcast model, the delivered time series will consist of hindcast time series for a few locations across the site, as well as a directional wave spectrum time series for one location on the site.
- For the Comprehensive Scope: Will use a local hindcast model, i.e. taking local high-accuracy bathymetry into account, and use site-specific model calibration. Integral parameter- and directional spectrum-time series will be available across the site. The model data delivered will be thus be more extensive than that delivered as part of the tender for the recent Danish Offshore Wind Farms (Horns Rev 3, the Nearshore sites, and Kriegers Flak), and will be more akin to that for Hollandse Kust Noord in the item *Metocean Database HKN* here: https://offshorewind.rvo.nl/windwaternh.

METOCEAN – SCA MARINE PARAMETERS

ENERGINET

Category 2b: SCA – Marine parameters and their correlations with the wind

The intended Report contains a hindcast model description, validations against measurement data, and extreme value analysis results.

- For the Default Scope, the report will contain:
  - An undetailed description of the regional hindcast model.
  - Validation plots and statistical validation parameters for those of the measurement stations in the slide *Measurement Datasets* that have both available data and are far enough away from the coast to give reasonable hindcast modelling results. The purpose of this is to reveal any hindcast model uncertainties and biases.
  - Extreme value analysis results of 1-, 10-, 50-, and 100-year omnidirectional H_{m0}, H_{max}, and maximum crest elevation C_{max}.
  - Tidal level analysis results: HAT, MHWS, MHWN, MSL, MLWN, MLWS, and LAT.
  - A plausibility statement from an independent third party.

- Items contained in neither the Default Scope nor in the Comprehensive Scope:
  - Seabed movement and scour.
  - Weather window- and downtime analyses.

METOCEAN – SCA MARINE PARAMETERS

ENERGINET

Category 2b: SCA – Marine parameters and their correlations with the wind

The intended Report contains a hindcast model description, validations against measurement data, and extreme value analysis results.

- For the Comprehensive Scope, the report will contain:
  - A detailed description of the local hindcast model, its bathymetry, setup parameters, convergence, and calibration.
  - Validation plots and statistical validation parameters for most of the measurement stations with available data in the slide *Measurement Datasets*. The purpose of this is to reveal any model uncertainties and biases.
  - Comprehensive extreme value analysis of 1- through 10000-year directional H_{m0}, H_{max}, omndirectional C_{max}, current speeds (total and residual currents), and water levels.
  - Joint probability analyses of select pairs of the parameters from the bullet point immediately above.
  - Tidal level analysis results: HAT, MHWS, MHWN, MSL, MLWN, MLWS, and LAT.
  - Analyses of salinity, water temperature ranges, and water density.
  - An analysis of the occurrence of breaking wave types.
  - The scope is similar to that of the *Report – Metocean Study* here: https://offshorewind.rvo.nl/windwaterzh, although without wind shear-, extreme wind speed-, and turbulence analyses.
  - A certification report or similar, against IEC 61400-3-1 (2019), from an accredited certification body.

Dialogue Question M8:

For the hindcast dataset (the slide before last) and reporting (the preceding slide, and this slide), please state your preference for the Default Scope or Comprehensive Scope, and outline the impact each would have on your bid.

METOCEAN – OTHER SCA PARAMETERS

ENERGINET

Category 2c: SCA – Other SCA Parameters

- For the Default Scope:
  - No analyses of lightning, tsunamis, earthquakes, solar radiation, and icing on blades.

- For the Comprehensive Scope:
  - A report containing analyses of lightning, tsunamis, earthquakes, solar radiation, and icing on blades.
  - A certification report or similar, against IEC 61400-3-1 (2019) from an accredited certification body.

Dialogue Question M9:

Please state your preference for the Default Scope or Comprehensive Scope for this topic, and outline the impact each would have on your bid.