



Energistyrelsen

APPENDIX 3, CAPABILITY-BASED TWO-WAY CONTRACT FOR DIFFERENCE

for the Agreement regarding [North Sea I, South Offshore Wind Farm/ North Sea I, Mid Offshore Wind Farm].



TABLE OF CONTENT

1.	INTRODUCTION	5
2.	THE PRINCIPLES OF THE CAPABILITY-BASED TWO-WAY CONTRACT FOR DIFFERENCE	5
2.1	Capability-based two-way Contract for Difference	5
2.2	Cap on payment from the Danish State to the Concessionaire	6
2.2.1	Index regulation of the cap on payment from the Danish State to the Concessionaire	7
2.3	Subsidy payments in specific situations	7
2.3.1	Forced downregulation and curtailment	7
2.3.2	Negative prices	8
2.3.3	Scheduled Maintenance	8
3.	METHODOLOGY TO BE USED FOR ESTABLISHING THE AVAILABLE ACTIVE POWER (AAP) LOOK UP TABLE AND REPORTING REQUIREMENTS UNDER THE CAPABILITY-BASED TWO-WAY CFD SUBSIDY SCHEME	8
3.1	Overview of the methodology	8
4.	CREATION OF THE DATABASED AAP LOOK-UP TABLE	9
4.1	Requirements regarding the databased AAP look-up table	9
4.1.1	Requirements regarding ranking the upstream Turbines incl. overplanting	9
4.1.2	Requirements regarding the creation of the data-based look-up AAP-table	13
4.2	Requirements regarding third party verification of the data-based AAP look-up table	16
4.3	Requirements regarding deadline for submission of the databased AAP look-up table	17
5.	USE OF THE AAP LOOK-UP TABLE IN THE OPERATIONAL PHASE	17
5.1	Requirements regarding monthly submission of data	18
5.2	Correction of AAP for CfD payment	19



5.3	Requirements regarding recalibration of the databased AAP look-up table	20
5.4	Settlement control	21
5.5	Standards governing the signals used in the AAP methodology	22



Appendices:

Appendix 3.1: Estimation of Available Active Power for Two-Way CfD in Offshore Wind Energy Application

Appendix 3.2: Instructions for the audit of capability reporting

[Guidance for the potential tenderer and relevant economic operators in the market

dialogue: *The Danish Energy Agency has prepared this Appendix 3, Capability-Based Two-Way Contract for Difference, containing a draft of the overall description of the capability-based two-way Contract for Difference (CfD) subsidy scheme concerning [North Sea I, South / North Sea I, Mid] Offshore Wind Farm, covered by the Agreement, as well as draft of the detailed requirements for the methodology to be used for establishing the available active power (AAP) look up table and reporting requirements under the capability-based two-way CfD subsidy scheme.*

The aforementioned methodology has been developed by Technical University of Denmark, Department of Wind Energy and Systems, and the technical report containing the methodology is attached to this Appendix as Appendix 3.1.

Please be advised if there is any conflict, ambiguity or discrepancy, the priority of the documents shall be in accordance with the following sequence:

- 1) *Appendix 3: Capability-Based Two-Way Contract for Difference*
- 2) *Appendix 3.1: Estimation of Available Active Power for Two-Way CfD in Offshore Wind Energy Application]*



1. INTRODUCTION

This Appendix 3, (Capability-Based Two-Way Contract for Difference), contains an overall description of the principles of the capability-based two-way Contract for Difference (CfD) subsidy scheme concerning [North Sea I, South / North Sea I, Mid] Offshore Wind Farm, covered by the Agreement.

Furthermore, this Appendix sets out the detailed requirements for the methodology to be used for establishing the available active power (AAP) look up table and reporting requirements under the capability-based two-way CfD subsidy scheme.

2. THE PRINCIPLES OF THE CAPABILITY-BASED TWO-WAY CONTRACT FOR DIFFERENCE

2.1 Capability-based two-way Contract for Difference

As stated in the Concession Agreement, Sub-Clause 11.1, the Concessionaire of [North Sea I, South/North Sea I, Mid] Offshore Wind Farm, will receive subsidies for the electricity produced from the Minimum Capacity in the form of a capability-based two-way CfD subsidy scheme for a period of 20 years.

Under the capability-based two-way CfD subsidy scheme the Concessionaire will receive subsidies up to a specified cap in the form of a payment from the Danish State when the Strike Price is higher than the Reference Price, cf. Sub-Clause 11.2 of the Concession Agreement, as further described below. Correspondingly, in periods where the Strike Price is lower than the Reference Price, the Concessionaire must make payment to the Danish state, cf. Sub-Clause 11.3 of the Concession Agreement. There is no cap on the payments from the Concessionaire to the Danish State and there is no option for the Concessionaire to opt-out of the subsidy scheme.

To exemplify the functioning of the capability-based two-way CfD, the Concessionaire will be required to make payments to the Danish State in a situation where for instance the Strike Price is DKK 303.70 per MWh, while the Reference Price for a given month is DKK 400 per MWh. In this event, the Concessionaire will be liable to pay the Danish State DKK 96.30 per MWh.

The calculation of the amount of the settlement, pursuant to Sub-Clauses 11.2 and 11.3 of the Concession Agreement, is based on the calculated power production capability of the Offshore Wind Farm under the given conditions, also referred to as Available Active Power (AAP) or capability as further described below in section 3.1. The methodology to be used and the requirements to be complied with by the Concessionaire when determining the relevant AAP is set out in more detail in sections 3-5 below.

As set out above, the settlement between the Danish State and the Concessionaire is based on the difference between the Strike Price and the Reference Price, applied to the Concessionaire's potential production, Available Actual Production (AAP), for each settlement period of a month 'm', where:

- The *Strike Price* is a fixed price per unit of electricity in "DKK"/MWh, cf. the Concession Agreement, Sub-Clause 2.49.



- The *Reference Price_m* is calculated by the DEA as a simple average of the Day-Ahead Prices for a calendar month in the day-ahead market for the bidding zone in which the Offshore Wind Farm is located, cf. the Concession Agreement, Sub-Clause 2.46. For the calculation of the Reference Price, the price adjustments pursuant to section 2.3. shall apply.

The *AAP_m* is the maximum power production capability of the Turbine(s) during particular wind conditions, (i.e. wind speed, wind direction and turbulence intensity), in month 'm', cf. section 3 and 4 below.

The payment obligation, pursuant to Sub-Clause 11.2 and 11.3 of the Concession Agreement, is determined pursuant to formula (1) of this Appendix, where settlement for month 'm' is the difference between the Strike Price and the Reference Price, times [potential production], calculated based on the formula (1):

$$(1) \quad \textit{Payment}_m = \textit{AAP}_m * (\textit{Strike Price} - \textit{Reference Price}_m)$$

Pursuant to Clause 11.2.1 of the Concession Agreement, if the Reference Price exceeds the Strike Price for a given period (resulting in a negative difference), the Concessionaire shall pay the Danish State an amount equal to *Payment_m*. This ensures that when Reference Price exceeds the Strike Price, the excess revenue — based on the Concessionaire's potential production volume — is received by the Danish State.

Conversely, in accordance with Clause 11.3.1 of the Concession Agreement, if the Strike Price exceeds the Reference Price in a given period (resulting in a positive difference), the Danish State shall pay the Concessionaire an amount equal to *Payment_m* for that period. This ensures the Concessionaire receives compensation when the Reference Price falls below the Strike Price, calculated based on the Concessionaire's potential output during that month and the price shortfall.

2.2 Cap on payment from the Danish State to the Concessionaire

A cap on payment from the Danish State to the Concessionaire of the amount of [13.1/9.1] billion DKK excl. VAT (2025-prices) for [North Sea I, South / North Sea I, Mid], cf. Sub-Clause 11.3.2 of the Concession Agreement, is imposed on the total net payments from the Danish state to the Concessionaire, cf. Sub-Clause 11.3.1 of the Concession Agreement, over the 20-year period the CfD-mechanism is active.

The cap is defined as a net cap, meaning that payments made by the Concessionaire to the Danish State are credited toward the cap, while subsidy payments made by the State to the Concessionaire are deducted from the cap. In the event of payments to the state in the first period(s), cf. Sub-Clause 11.2.1 of the Concession Agreement, the cap increases accordingly. It is therefore a net cap from the outset. If the cap is fully utilized, no further subsidy payments will be made to the Concessionaire. However, if the Concessionaire subsequently makes payments to the State (e.g., due to the Reference Price exceeding the Strike Price), the cap will be replenished by the corresponding amount. The Concessionaire will then become eligible to receive new subsidy payments from the State, up to an amount equal to the payments made to the State.



2.2.1 Index regulation of the cap on payment from the Danish State to the Concessionaire

As the cap is set in 2025-prices, the net cap will be price indexed, cf. Sub-Clause 11.3.2 of the Concession Agreement, over the 20-year duration of the subsidy scheme. The price index used is the net price index (in Danish "Nettoprisindekset"), as published by Statistics Denmark (in Danish "Danmarks Statistik"). Price indexation starts from 1 June 2025 and at 1 January of each year, the updated cap is regulated using the net price index for September in the previous year.

The net cap in billion DKK for 2026 is given by:

$$(2) \quad \text{net cap}_{2026} = [\text{North Sea I, South: 13.1} / \text{North Sea I, Mid: 9.1}] * \left(\frac{NPI_{\text{September 2025}}}{NPI_{\text{May 2025}}} \right)$$

From year 2026 and onwards, the updated net cap in billion DKK in year y is given by:

$$(3) \quad \text{Net cap}_y = (\text{net cap}_{y-1} - \text{payment}_{y-1}) * \left(\frac{NPI_{y-1}}{NPI_{y-2}} \right)$$

Where:

- $y > 2026$
- If $\text{payment}_y > 0$, then $\text{payment}_y \leq \text{net cap}_y$
- payment_{y-1} is the sum of the monthly payments in year $y - 1$ based on formula (1)
- NPI_{y-i} is the net price index for September in year $y - i$
- $\text{net cap}_y \geq 0$, i.e., the net cap cannot be negative.

The last point implies that when the net cap is depleted, the Concessionaire can only receive a payment from the Danish State, cf. Sub-Clause 11.3.1 of the Concession Agreement, again after a year where the Concessionaire has made a net payment to the Danish State, cf. Sub-Clause 11.2.1 of the Concession Agreement..

If the net price index published by Statistics Denmark is not available, the DEA will select another corresponding price index.

2.3 Subsidy payments in specific situations

2.3.1 Forced downregulation and curtailment

During forced downregulation and curtailment, i.e. reduction in production, payments between the Danish State and the Concessionaire will occur according to formula (1), cf. section **Fejl! Henvisningskilde ikke fundet.** above. If the Concessionaire chooses to trade in the balancing markets on market terms, the Concessionaire will still be subject to the terms of this subsidy scheme, regardless of the bids in the balancing market. Similarly, in case of forced downward regulation, the subsidy scheme will continue to apply.



2.3.2 **Negative prices**

In case of the Day-Ahead Price being negative, i.e., the Day-Ahead Price is below 0 DKK, in a given market time unit, the Day-Ahead Price is set at 0 DKK/MWh in calculation of the Reference Price. During negative prices, settlement between the Danish State and the Concessionaire will occur according to formula (1), cf. section **Fejl! Henvisningskilde ikke fundet.** above.

2.3.3 **Scheduled Maintenance**

During scheduled maintenance, settlement between the Danish State and the Concessionaire will occur according to formula (1), cf. section **Fejl! Henvisningskilde ikke fundet.** above.

3. **METHODOLOGY TO BE USED FOR ESTABLISHING THE AVAILABLE ACTIVE POWER (AAP) LOOK UP TABLE AND REPORTING REQUIREMENTS UNDER THE CAPABILITY-BASED TWO-WAY CFD SUBSIDY SCHEME**

Section 3-5 of this Appendix 3, (Capability-Based Two-Way Contract for Difference) sets out the methodology to be used by the Concessionaire when creating the databased AAP look-up table required pursuant to Sub-Clause 10.1 of the Concession Agreement, which shall be used as a basis for the settlement under the capability-based two-way CfD scheme applicable to the Agreement. This appendix furthermore sets out the requirements to be fulfilled by the Concessionaire under the Agreement in terms of providing data to the DEA under the capability-based two-way CfD subsidy scheme. Reference is furthermore made to Clauses 10 – 11 of the Concession Agreement and Appendix 3 (Capability-Based Two-Way Contract for Difference), and Appendix 3.1 (Estimation of Available Active Power for Two-Way CfD in Offshore Wind Energy Application) and Appendix 3.2 (Instructions for the audit of capability reporting).

3.1 **Overview of the methodology**

The capability based two-ways CfD subsidy scheme applicable to the Agreement is settled based on the potential power generation of the Offshore Wind Farm and not the actual power production. The potential power generation is an estimate of the power which the Offshore Wind Farm could have generated in a given hour under the given conditions, referred to as Active Available Power (hereinafter referred to as “AAP”), as opposed to what was actually produced.

The AAP is defined as the maximum power production capability of the Turbine(s) during particular wind conditions, i.e. wind speed, wind direction and turbulence intensity. Modern wind turbines have an associated signal in their Supervisory Control and Data Acquisition system (hereinafter referred to as “SCADA system”), called *available* or *possible power*. This provides AAP at the individual turbine level, based on local wind speed experienced by the turbines within an offshore wind farm. Under normal operation of an offshore wind farm, the SCADA signal providing the AAP is equal to the maximum power production capability of a turbine.



The methodology behind the requirements described below, focuses on the ‘upstream’ wind conditions that are not impacted by wake effects and are independent of the operational state of the offshore wind farm, e.g. independent on whether the offshore wind farm is operating on maximum power production capacity, shut down etc. The methodology is a data-based approach that utilises a comprehensive databased AAP look-up table, to be created by the Concessionaire, cf. the requirements stated below in section 4. The databased AAP look-up table creates a multi-dimensional offshore wind farm power curve. For each combination of input parameters, i.e., wind speed, wind direction and turbulence intensity, the data-based AAP-table assigns a corresponding AAP output of the Offshore Wind Farm under normal operation, which corresponds to the available active power output (“AAP-output”). Thus, the databased AAP look-up table can be used to determine the potential power generation that the Offshore Wind Farm could provide according to the measured input parameters.

The databased AAP look-up table is to be created based on the layout of the Offshore Wind Farm.

4. CREATION OF THE DATABASED AAP LOOK-UP TABLE

4.1 Requirements regarding the databased AAP look-up table

The Concessionaire shall create a databased AAP look-up table based on the requirements stated in this section 4.

When creating the databased AAP look-up table—the Concessionaire shall initially rank all Turbines of the Offshore Wind Farm to determine which Turbines are the most upstream, cf. the requirements stated in section 4.1.1, after which the Concessionaire shall proceed to create the databased AAP look-up table based on measurements from the most upstream Turbines for each input parameter, cf. the requirements stated in section 4.1.2.

4.1.1 Requirements regarding ranking the upstream Turbines incl. overplanting

When creating the databased AAP look-up table, the Concessionaire must follow the method described in this Appendix. This implies that the Concessionaire shall rank all the Turbines of the Offshore Wind Farm in order to determine which Turbines are the most upstream, i.e., first to face the wind and least affected by wake effect from other Turbines, by using both the wind directions and the positions of all the Turbines, as further described below.

For the avoidance of doubt, the ranking of all the Turbines within the Offshore Wind Farm includes all Turbines constituting the Minimum Capacity and all Turbines constituting the Overplanting Capacity, if the Concessionaire chooses to establish Overplanting Capacity and if Overplanting Capacity is established at the time of



creation of the databased AAP look-up table. Turbines forming the Overplanting Capacity cause wake effects which will interfere with the measurements of the downstream Turbines from the Minimum Capacity. Therefore, Turbines from the Overplanting Capacity are part of the input in the databased AAP look-up table, but not the AAP-output determined through the databased AAP look-up table.

When ranking the Turbines of the Offshore Wind Farm, the Concessionaire shall group the Turbines into layers of Turbines that are equally upstream, e.g where Turbines in layer one (1) are not in the wake of any other Turbines and Turbines in layer two (2) are only in the wake of Turbines in layer one (1) etc. See figure 1 below for an illustrative example.

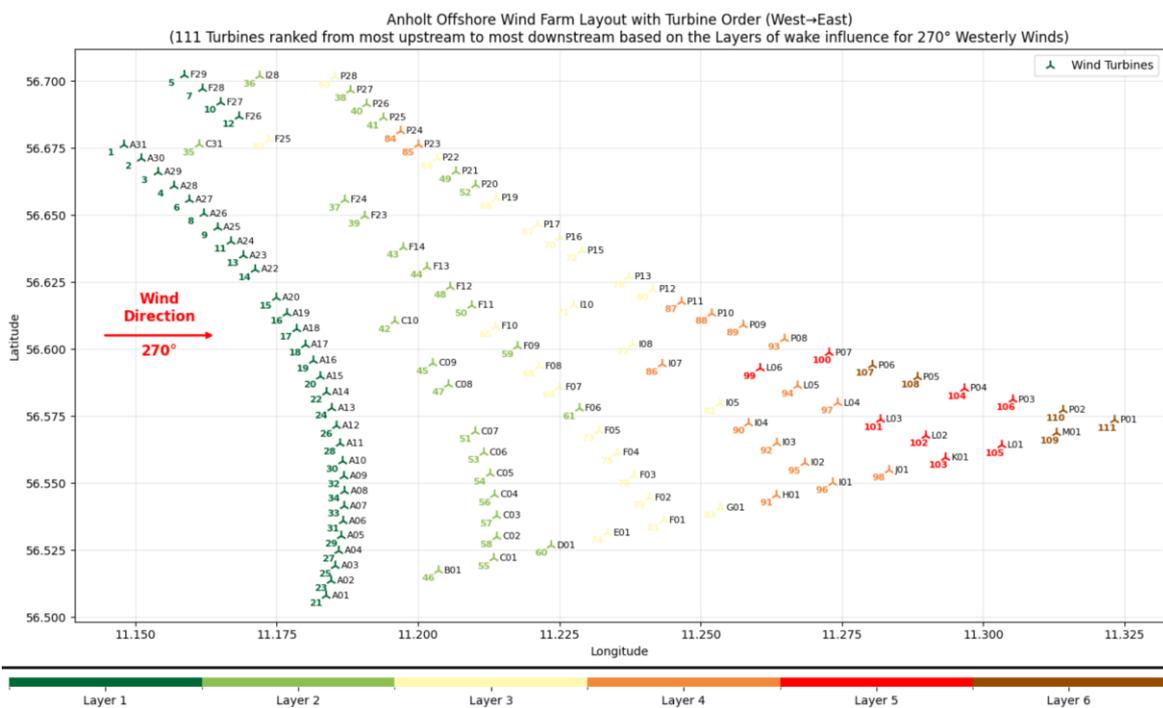


Figure 1 – Ranking of upstream turbines (1,2,3, ..., 111) in Anholt wind farm for westerly winds (median wind direction in the wind farm is within $270^{\circ} \pm 5^{\circ}$). Layer 1 turbines are all upstream, Layer 2 under the influence of Layer 1 turbines. Layer 3 is affected by both Layer 2 and Layer 1, and so on. The ranking within the Layers is performed based on the most upwind turbines (where the wind hits first).

The Concessionaire shall determine which Turbines are the most upstream by using the wind direction and the positions of all the Turbines.

When conducting measurements of the wind directions in order to determine which Turbines are the most upstream, the Concessionaire shall measure all possible wind directions towards the Offshore Wind Farm, which is referred to as the reference wind direction, WD_{ref} , with 5 degree intervals, where the Turbines are



ranked from the most upstream to the most downstream Turbines, $(T_{up_1}, T_{up_2}, T_{up_3}, \dots, T_{up_{last}})$, based on their positions within the Offshore Wind Farm including Overplanting Capacity if relevant.

For the reference wind direction WD_{ref} (e.g., 270° for westerly wind) the following method shall be used to divide the Turbines into layers:

1. **Wake cone definition:**

A sector that assumes a wake spreading or wake expansion of 10° around the wind direction.

2. **Coordinate system conversion**

To check if a Turbine is upstream or downstream for a given (meteorological) wind direction, WD_{ref} (with 0° North, 90° East etc.), a conversion to trigonometric coordinates (with 0° East, 90° North etc., within 0° to 360° degrees) is applied:

$$WD_{trig} = (270 - WD_{ref}) \bmod 360$$

3. **Directional angle calculation:**

We calculate the directional angle ($\theta_{A \rightarrow B}$) for every Turbine pair ($A \rightarrow B$), where x is the longitude, y is the latitude of the Turbine locations.

$$\theta_{A \rightarrow B} = \arctan2(y_B - y_A, x_B - x_A)$$

Without additional processing, this gives the angle in degrees from East (counterclockwise), i.e. in trigonometric coordinates.

• **Wake condition check:**

Turbine B is considered **downstream** of A (i.e., B is in A's wake) if both **Condition #1** and **Condition #2** is true:

- **Condition #1** is to check if the directional angle falls within the reference wind direction sector \pm wake cone:

$$WD_{trig} - 10^\circ \leq \theta_{A \rightarrow B} \leq WD_{trig} + 10^\circ$$

- **Condition #2** is to check that Turbine B is physically upwind of A in trigonometry coordinates:

$$(x_B - x_A) * \cos(WD_{trig}) + (y_B - y_A) * \sin(WD_{trig}) > 0$$

• **Layer identification:**

Turbines are grouped into layers based on their exposure to wakes for the given wind direction:

- Layer 1: Wake-free Turbines (no upstream Turbines are affecting them)
 - If either Condition #1 or #2 is FALSE for **all** Turbines A relative to Turbine B, then Turbine B is not considered downstream of any Turbines for that wind direction. That means Turbine B is in Layer 1.
- Layer 2: Turbines only affected by Layer 1
- Layer N: Turbines affected by Turbines in Layers 1 to N-1.



This allows the Concessionaire to evaluate the conditions for wake criteria (e.g., 10° wake cone) for the particular Offshore Wind Farm layout and select the most representative upstream Turbines within Layer 1.

- **Unique ranking:**

Turbines are ranked by how far upwind they are for the given wind direction (i.e., where the wind hits first). This ranking uses the meteorological wind direction, WD_{ref} , directly.

- Calculate wind-aligned position for each Turbine i within each layer via multiplying longitude x_i with East-West influence $\sin(WD_{ref})$ and latitude y_i with North-South influence $\cos(WD_{ref})$

$$wind - aligned\ position_i = x_i * \sin(WD_{ref}) + y_i * \cos(WD_{ref})$$

A higher wind-aligned position means the Turbine is further upwind (the wind hits it first).

- Sort Turbines from highest to lowest wind-aligned position
- Assign ranks sequentially (highest = most upstream)

Table 1 represents an illustrative example from Anholt offshore wind farm, where the Turbines have been ranked in accordance with the conditions stated above.

Wind direction [deg]	Upstream turbine ranking [turbine ID] $T_{up_1}, T_{up_2}, T_{up_3}, \dots, T_{up_{109}}, T_{up_{110}}, T_{up_{111}}$
...	...
[5-10)	P28, I28, F29, ..., A03, A02, A01
...	...
[95-100)	P01, P02, M01, ..., A19, A15, A16
...
[175-180)	A01, A02, B01, ..., P27, P28, I28
....
[270-275)	A31, A30, A29, ..., M01, P02, P01
....
[355-0)	F29, I28, P28, ..., A02, A04, A03

Table 1 - Upstream-to-downstream turbine ranking ($T_{up_1}, T_{up_2}, T_{up_3}, \dots, T_{up_{109}}, T_{up_{110}}, T_{up_{111}}$) by turbine ID for selected wind direction intervals at Anholt Offshore Wind Farm. For each wind direction sector (e.g., [5–10°)), turbines are listed from most upstream (first to face the wind) to most downstream (last to face the wind), as determined by their spatial position relative to the incoming wind. An example Python script for the methodology as applied in Anholt can be seen [here](#).



4.1.2 Requirements regarding the creation of the data-based look-up AAP-table

The Concessionaire shall create the data-based AAP look-up table by conducting measurements of the input parameters of the table: 1) wind direction, 2) wind speed, and 3) turbulence intensity for each layer of upstream Turbines, cf. the requirements stated in section 4.1.2.1 below,

For each input parameters of each layer of upstream Turbines, the Concessionaire shall then measure the capacity when the Offshore Wind Farm is operating on maximum power production capacity, cf. the requirements stated in section 4.1.2.2 below, which will constitute the AAP-output for a specific wind speed, wind direction and turbulence intensity in the databased AAP look-up table.

When creating the databased AAP look-up table from the time of achievement of the Operational Capability Minimum Capacity, as stated in Sub-clause 7.3.1. of the Concession Agreement, the whole Offshore Wind Farm shall be operational as well as all of the Turbines for the databased AAP look-up table to represent the whole Offshore Wind Farm.

4.1.2.1 Requirements regarding measurements of input parameters

The Concessionaire shall conduct measurements from the three most upstream Turbines, utilizing the wind direction and the positions of all the Turbines, cf. the requirement stated in section 4.1.1., on the basis of the SCADA signals (i.e., *[insert definition]*) in 10-min statistics (i.e., 10-min average and standard deviation).

The Concessionaire shall proceed the measurements when all the Turbines are “on” and when the Offshore Wind Farm are under normal operation, i.e., no downregulation or boosting in any of the Turbines. For the avoidance of doubt, the proceeding of the measurements include the use of Turbine Status Code i.e., wtur_TurSt_<turbine ID>) signal in SCADA, where normal operation is indicated as wtur_TurSt_<turbine ID>=1.0.

For the reference, the availability across the wind farm, $WF_{availability}$, shall be defined using the following method:

$$WF_{availability} = \frac{\text{Number of Turbines with Status Code}=1 \text{ (for normal operation)}}{\text{Total number of Turbines}} \quad (1)$$

The Concessionaire shall adjust the nominator of equation 1, if the Turbine Status Code is defined differently in the SCADA (i.e., other than =1). The output column of the databased AAP look-up table is the park-level power output (wind farm power) under the condition where the SCADA signal is = 1.

When generating the databased AAP look-up table, the Concessionaire shall calculate inputs for the wind farm power curve (i.e., *[insert definition]*) by using the following method:

- 1) **Wind direction:** median of the 10-min mean Nacelle Direction (*i.e.*, [the mean wind direction between all wind turbine generators]) extracted from ALL the Turbines' SCADA. Nacelle Direction signal is not significantly affected by the wake; therefore, it does not require correction between the normal and downregulated operation at the downstream Turbines. The use of the median across the full Offshore Wind Farm (rather than only the upstream Turbines) provides a more robust signal, avoiding potential availability or bias issues.

$$WD_{up} = median(WD_{T_{up_1}}, WD_{T_{up_2}}, WD_{T_{up_3}}, \dots, WD_{T_{up_{last-1}}}, WD_{T_{up_{last}}}) \quad (2)$$

- 2) **Wind speed:** average of the 10-min mean Rotor Effective Wind Speed (REWS) from the three upstream Turbines' SCADA

$$WS_{up} = avg(REWS_{T_{up_1}}, REWS_{T_{up_2}}, REWS_{T_{up_3}}) \quad (3)$$

- 3) **Turbulence intensity:** average of the 10-min standard deviation of the Rotor Effective Wind Speed signals across the three upstream Turbines, divided by the calculated wind speed (WS_{up}) in step 2

$$TI_{up} = avg(\sigma_{REWS_{T_{up_1}}}, \sigma_{REWS_{T_{up_2}}}, \sigma_{REWS_{T_{up_3}}}) / WS_{up} \cdot 100 \quad (4)$$

4.1.2.2 Requirements regarding measurements of the capacity constituting the AAP-output

The Concessionaire shall measure the injection of the supported part of the Offshore Wind Farm at the offshore substation. See figure 2 below for an illustrative example. For the avoidance of doubt, only measurements at the Offshore Wind Farm at normal operation are eligible (*i.e.*, when all Turbines constituting the Minimum Capacity and all Turbines constituting the Overplanting Capacity, if relevant, are operational).

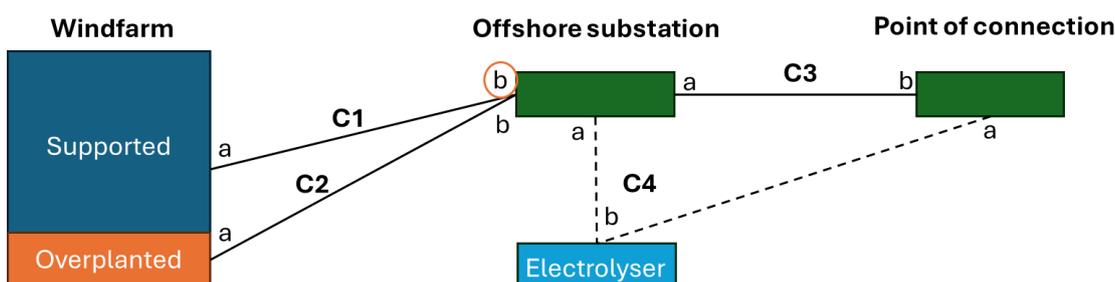


Figure 2 - Schematic illustration of the Offshore Wind Farm in case of overplanting with electrolyser. Cables are denoted as C with start point a and end point b. The operator may choose the cable to a potential electrolyser (C4) to start at the offshore substation or the onshore point of connection.

For sorting the reference group measurements into bins (or intervals) for each input parameter the following method shall be used to complete the databased AAP look-up table:



- **Wind speed, WS_{up} :**
 - 0.5 m/s steps between 1 m/s below the cut-in to 2 m/s above the rated wind speed of the Turbines used in the Offshore Wind Farm.
 - 2 m/s steps between 2 m/s above the rated to 1m/s above the cut-in wind speed of the Turbines used in the Offshore Wind Farm.
 - The safety factors of 1 m/s and 2 m/s account for potential added variance in the Rotor Effective -wind Speed SCADA signals compared to reference wind speeds used in the product catalogue of the Turbines.
- **Wind direction, WD_{up} :** 5-degree steps covering 0-360 degrees
- **Turbulence Intensity, TI_{up} :**
 - 1% steps between 2% and 10% (due to stronger wake effects to be corrected under curtailment in the lower TI region)
 - 2% steps between 10% and 30%
 - 30% upper limit is to be corrected if a higher upstream TI is observed at the site

For the avoidance of doubt the calculating of the average inputs and outputs for each bin, creates a representative Offshore Wind Farm-level AAP value for conditions within each interval, simplifying the table and making it more broadly applicable.

A representative databased AAP look-up table example is presented in **Fejl! Henvisningskilde ikke fundet.** below.

Inputs (averages of the upstream Turbines)			Output
Wind speed, WS_{up} [m/s]	Wind direction, WD_{up} [deg]	Turbulence intensity, TI_{up} [%]	Wind farm capability, AAP [MW]
...
[5-5.5)	[5-10)	[3 - 4)	20
[5-5.5)	[5-10)	[4 - 5)	25
....
[5-5.5)	[10-15)	[3 - 4)	20
...
[10.5-11)	[260-265)	[10 - 12)	500
....
[16-18)	[5-10)	[3 - 4)	1000
[16-18)	[5-10)	[4 - 5)	1000
....



[24-26)	[355-0)	[28 -30)	1000
---------	---------	----------	------

Table 2 - Representative databased AAP look-up table for AAP: Park level aggregated Active Power output as a function of binned upstream wind speed, wind direction, and turbulence intensity, derived from SCADA data of the turbines. If, for example, the wind speed is measured between 10.5 and 11 m/s and the wind direction between 260 and 265 degrees and the turbulence intensity between 10 and 12 %, then the databased AAP look-up table determines the wind farm AAP at 500 MW for the 10-min period associated with the inputs.

The Concessionaire is solely responsible for creating a complete databased AAP look-up table that provides an accurate description of the AAP of the Offshore Wind Farm under all combinations of the wind speed, wind direction and turbulence obtained within twelve (12) months.

For the avoidance of doubt, the Concessionaire shall use all twelve (12) months to create the databased AAP look-up table, wherein the Concessionaire is undertaking measurements, cf. requirements stated in the preceding sections for ensuring a representative databased AAP look-up table.

It is noted that input combinations (i.e, wind characteristics) that are not determined at generation or re-calibration, cf. below, of the table (i.e., empty rows) are not settled. The Concessionaire shall to the extent possible undertake the measurements, cf. requirements stated in section 4.1., until adequately precise inputs and outputs are gathered to complete in the databased AAP look-up table.

4.1.2.3 *Requirements regarding Overplanting Capacity, if relevant*

If the Concessionaire chooses to overplant, the Concessionaire must identify the Overplanting Capacity as a series of Turbines and Inter-array cables. A layout of the Offshore Wind Farm with Global Service Relation Number (hereinafter referred to as "GSRN") from the DEA Master Data Registry and clear identification must be sent to the DEA in PDF with the databased AAP look-up table and is a prerequisite for approval of the databased AAP look-up table. If the Concessionaire chooses to overplant, the Concessionaire must design a technical setup, in which production from supported Turbines and overplanted Turbines can be measured separately. A written explanation of the technical setup must be sent to the DEA.

4.2 **Requirements regarding third party verification of the databased AAP look-up table**

When the databased AAP look-up table is completed in accordance with the requirements stated in section 4.1, the Concessionaire shall have the databased AAP look-up table verified by an **[independent third party]**



4.3 Requirements regarding deadline for submission of the databased AAP look-up table

The Concessionaire shall send the databased AAP look-up table, cf. section 4.1, verified in accordance with the requirements stated in section 4.2, to the DEA within the deadline stated in Sub-Clause 10.1.4 of the Concession Agreement.

Together with the databased AAP look-up table, the Concessionaire shall also submit information regarding Overplanting Capacity, if relevant, cf. section 4.1.2.3.

In order to be able to submit the databased AAP look-up table and additional required documentation the Concessionaire must do the following:

- Register as a user in the DEA's: "Selvbetjeningsportal" on the following link <https://ens.dk/indberetninger/selvbetjeningsportal>. Please note that a registration in this system requires MitID.
- Submit the data as specified above in "Selvbetjeningsportal" using an upload file function. The data must be structured in accordance with the format specified in the template Appendix 3.1 (Estimation of Available Active Power for Two-Way CfD in Offshore Wind Energy Application).

Once the DEA has approved the databased AAP look-up table, the DEA will notify the Concessionaire hereof by way of a written confirmation.

5. USE OF THE DATABASED AAP LOOK-UP TABLE IN THE OPERATIONAL PHASE

Once the databased AAP look-up table is approved by the DEA it will enter into force and the Concessionaire must use the data collected during the creation period for the databased AAP look-up table as well as the finalised databased AAP look-up table to calculate AAP for the look-up table creation period (first 12 months after Operational Capability Minimum Capacity). Using the data and final databased AAP look-up table, the DEA will retroactively calculate the settlement for the creation period, cf. Sub-Clause 11.1.4 of the Concession Agreement.

During the operational phase and for the entire subsidy period (20 years), the Concessionaire must determine AAP using the databased AAP look-up table and input sources as described in this Appendix.

The wind data input for the databased AAP look-up table will depend on the operation of the wind farm,

- i. During normal operation, the wind data source is the rotor effective wind speed.
- ii. During downregulation, the wind data source is the rotor effective wind speed, with correction using the correction formulae.



- iii. During partial shutdown or limited availability, if the most upstream Turbines are not available, the rotor effective wind speed from three neighbouring Turbines (i.e. next most upstream Turbines) is used.
- iv. During shutdown or zero-availability,
 - a. nacelle installed lidar is used.
 - b. if no lidar is available e.g., due to technical issues, the nacelle anemometer is used.

The Concessionaire is required to install at least one lidar on a Turbine that is covered by the CfD support scheme.

AAP is to be determined at every 10-minute period (corresponding to the current practice for SCADA signals) by calculating the required inputs from extracted SCADA signals of the upstream Turbines and looking up the resulting AAP in the databased AAP look-up table. The Concessionaire must correct the AAP for available Turbines to correct for scheduled maintenance, downregulation and grid loss before sending the AAP to the DEA for CfD settlement, cf. section 5.2 below.

The Concessionaire must continuously measure and retrieve all necessary data in order to comply with the methodology described in this Appendix. Furthermore, the DEA can at any given time, request raw or aggregated measurement data which has been gathered by the Concessionaire.

5.1 Requirements regarding monthly submission of data

The Concessionaire shall monthly for the entire subsidy period of 20 years submit the data listed below to the DEA via a self-service portal “Selvbetjeningsportalen”, cf. Sub-Clause 10.3.1 of the Concession Agreement. Reporting is required on the following, in a 10-minute resolution, covering a calendar month:

- AAP based on the most recently calibrated and certified databased AAP look-up table
- Corrected AAP (equation 6 below in section 5.2)
- Actual production of the CfD supported part of the Offshore Wind Farm (e.g. Minimum Capacity) delivered in the offshore substation
- Actual production of the Overplanting Capacity of the Offshore Wind Farm delivered in the offshore substation, in order for the DEA to verify that production from the Overplanting Capacity is not part of either AAP or the actual production of the subsidised part of the Offshore Wind Farm.
- Actual consumption of an offshore power to X facility connected to the offshore substation
- The Offshore Wind Farm availability factor (equation 1 above in section 4.1.2.1.)

Furthermore, corrections to the reported AAP or the actual production delivered in the offshore substation for a relevant calendar month after the Concessionaire has initially submitted AAP and actual production to the DEA shall be reported by the Concessionaire to the DEA via “Selvbetjeningsportalen” without undue delay.



Information regarding downregulations and scheduled maintenance shall be sent to DEA by e-mail (ve-afregning@ens.dk). This information shall be sent at the same time as the registration of AAP and the actual production measured in the offshore substation for the related calendar month.

Raw wind and input signals mentioned in data package [to be defined] should not be sent to the DEA unless requested by the DEA. The DEA reserves the right to request all data mentioned in data packages [to be defined]. All data in the data packages must be generated on a continued basis to be used in third-party certification and should be available for delivery to the DEA within 1 month if requested.

5.2 Correction of AAP for CfD payment

The Concessionaire shall use a correction formula to apply to the AAP from the databased AAP look-up table to derive the final available active power value (AAP') which must be forms the basis for the CfD payments:

$$AAP'_m = \delta * \sum_{\tau=1}^T (WF_{availability_{\tau}} + SM_{\tau} + DR_{\tau}) * AAP_{\tau} \quad (6)$$

The Concessionaire needs to determine AAP' for every period t, where the time span covered by t is equal to the averaging period of the Reference Price and τ represents the granularity of the table data (i.e., 10 minutes).

The Concessionaire shall note that the above equation only regards the supported part of the Offshore Wind Farm as the output during the creation of the databased AAP look-up table is measured at a connection point (C_{1b} in figure 2) which has no connection to potential overplanted capacity.

AAP is corrected to AAP' in the following ways:

a) Grid losses

AAP_{τ} in Equation (6) above represents the output at the offshore substation, which does not account for grid losses occurring from the offshore substation to the point of connection. This can be approximated through a constant loss-factor ($\delta < 1$) which is fixed over time and is determined by technical specifications such as cable length and voltage. The fixed value δ is determined as the average relative difference of the measured total injection into the offshore substation and the point of connection during the databased AAP look-up table calibrating campaign. This average should be calculated over all 10min intervals during calibration (represented as T):

$$\delta = \sum_{\tau}^T \frac{(C_{1b_{\tau}} + C_{2b_{\tau}}) - C_{3b_{\tau}}}{C_{1b_{\tau}} + C_{2b_{\tau}}} = \sum_{\tau}^T 1 - \frac{C_{3b_{\tau}}}{C_{1b_{\tau}} + C_{2b_{\tau}}} \quad (7)$$

b) Deviations from nominal production

AAP_{τ} assumes full nominal production (i.e. 100% utilisation of the given resource) of all Turbines at any time, since this is how the databased AAP look-up table was created. Hence, AAP_{τ} must be reduced by the types of



non-availability that should not be included in the CfD payments (non-eligible non-availability), but occurred in Turbines of the supported part of the Offshore Wind Farm. Given the definition of $WF_{availability_\tau}$, its application in Equation (6) above reduces AAP_τ by all types of non-availability, including unscheduled and scheduled maintenance, as well as down-regulation. As potential production volumes lost due to scheduled maintenance should be supported, this type of non-availability is re-introduced by adding SM_τ , which represents the share of Turbines which were affected by scheduled maintenance in period τ :

$$SM_\tau = \frac{\text{Number of turbines under scheduled maintenance}_\tau}{\text{Total number of turbines}} \quad (8)$$

As potential production volumes lost due to downregulation should be supported, Equation (6) also corrects for downregulated operation based on the number of downregulated Turbines within the Offshore Wind Farm for the period τ that occurred either market-based or non-market based (as requested by Energinet).

$$DR_\tau = \frac{\text{Number of downregulated turbines}}{\text{Total number of turbines}} \quad (9)$$

Importantly, as the measurements of the Offshore Wind Farm output during the preparations of the databased AAP look-up table, cf. clause 2, are separated from potential Overplanted Capacity, it is ensured that only the applicable part of the Offshore Wind Farm receives support. Thus, the correction function above is independent of potential Overplanted Capacity.

5.3 Requirements regarding recalibration of the databased AAP look-up table

The Concessionaire is obligated to carry out a recalibration of the databased AAP look-up table in all of the following circumstances:

- a) The Concessionaire shall perform a recalibration of the databased AAP look-up table at regular period, at least once every three (3) years.
- b) If the Concessionaire fails to comply with the monthly maximum deviation requirements of $\frac{AAP_{corr\ month} - P_{C1b\ month}}{AAP_{corr\ month}} \leq 1\%$ by more than three (3) times per twelve (12) month period.
- c) The DEA is entitled to request the Concessionaire to recalibrate the databased AAP look-up table, (e.g., xxxx) by no more than once (1) per twelve (12) month period
- d) The Concessionaire is entitled to recalibrate the databased AAP look-up table, (e.g., xxxx) by no more than once (1) per twelve (12) month period



When recalibrating the databased AAP look-up table, the Concessionaire shall adhere to the requirements stated in section 4 above.

After every recalibrating of the databased AAP look-up table, the Concessionaire shall provide the DEA with the calibrated databased AAP look-up table certified by [the independent third party], cf. requirements stated in section 4.2.

During recalibration, the Concessionaire must use the non-calibrated databased AAP look-up table (the one which has most recently been approved by the DEA) to estimate AAP and still send monthly AAP data to the DEA. Hence, the DEA and Concessionaire will use the non-calibrated databased AAP look-up table to determine the volume for the CfD and the settlement until a re-calibrated databased AAP look-up table is finalised and approved. Once the re-calibration has finalised (with approval), the Concessionaire must send AAP from the re-calibration period for each month to the DEA. The DEA will use the monthly AAP from the re-calibrated certified databased AAP look-up table to calculate the difference in settlement and correct all the settlements made during the re-calibration period.

For the avoidance of doubt, recalibration on the request of the DEA or the Concessionaire may occur more often than described above during the establishment of the Overplanting Capacity.

5.4 Settlement control

The DEA will annually perform a settlement control of the payments to and from the Concessionaire. For the purpose of this control, the Concessionaire shall submit an auditor's statement from a certified registered auditor on the following issues:

- (1) Whether the calculation of the AAP is in accordance with the databased AAP look-up table.
- (2) Whether the measuring equipment used in the Offshore Wind Farm is serviced and maintained in accordance with relevant standards and certified by third-party.
- (3) Whether It-systems used to retrieve measurement data and calculate AAP in the Offshore Wind Farm is in accordance with relevant standards, cf. section 5.5, and certified by third-party.

The purpose of this control is to obtain a high degree of assurance that data generated and used to calculate the AAP is valid/correct.

The audit must be carried out at least once every 12 months and further at any time at the request of the DEA and the auditor's statement must be performed in accordance with Appendix 3.2 (Instructions for the audit of capability reporting).



5.5 Standards governing the signals used in the AAP methodology

The AAP methodology presented here relies on high-quality, standardised data from SCADA and nacelle-mounted lidar systems, namely:

- Nacelle Direction (10min average)
- Rotor Effective (or Equivalent) Wind Speed (10min average and standard deviation)
- Turbine Status (particularly to indicate if the Turbine is normal operation vs. shut down vs. downregulated / curtailed) (10min indicator i.e., 0, 1, 2, etc.)
- Nacelle Wind speed (via nacelle mounted anemometers, 10min average and standard deviation)
- Active Power (10min average)
- Nacelle mounted lidar wind speed (10min average and standard deviation)

The following IEC standards govern the communication, definition, and quality of these signals used:

- **IEC 61400-25 series:** This is the key standard for communication and information exchange in wind power plants. It defines how SCADA systems should model, name, and exchange data for interoperability across different turbine vendors and systems. The standard also specifies how to map this data to common communication protocols.
- **IEC 61400-12-1:** This standard specifies procedures for measuring wind turbine power performance, including the calculation of rotor effective (or equivalent) wind speed (REWS) and the use of 10-minute averages and standard deviations for wind speed signals.
 - **IEC 61400-12-1 Supplement** covers lidar-specific methods for calculating wind speed statistics.
- **IEC 61400-12-2:** Focuses on nacelle anemometry, detailing methods and uncertainty analysis for wind speed measurements taken from nacelle-mounted sensors.
- **IEC 61400-21:** Addresses power quality measurements.

While IEC standards are the primary reference for these signals, ISO standards such as ISO 14224 (reliability and maintenance data) may be relevant for structuring operational and maintenance data.