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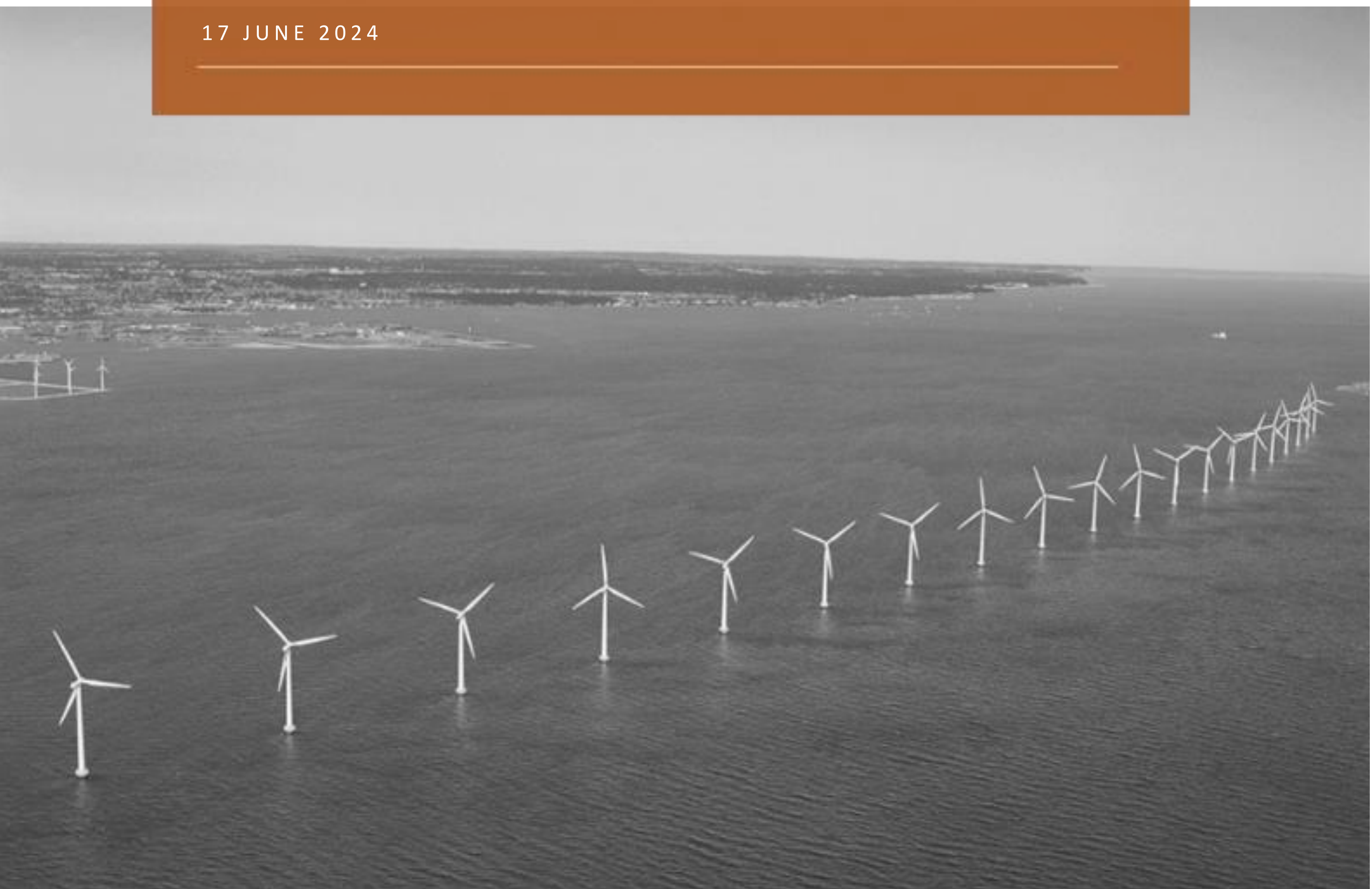
Energy Island Baltic Sea

WRF model for

Energy Island Baltic Sea

17 JUNE 2024



Energy Island Baltic Sea, WRF model

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2	2024-06-17	240514_22306_A_TS_1	All	WRF model report, final

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Executive Summary

Objective

The objective of this study is to investigate the impact of wind turbine wakes on the Energy Island Baltic Sea wind farm zone. The available model data does not take into account the existing and planned wind farms surrounding the Energy Island Baltic Sea wind farm zone. They therefore may give a false impression of the wind distribution across the site. By adding the influence of wind farms, some of the site parameters reported in the site wind conditions assessment [1] and the revalidation report for the site wind conditions assessment [2] can be updated.

Background

Energinet has commissioned the Energy Island project in the Baltic Sea. The Energy Island project is expected to generate significant amounts of renewable energy and reduce carbon emissions. As wind is the primary source of energy for the project, a thorough assessment of the site wind conditions is crucial for its successful implementation.

Measurements on site were conducted on two locations, Position 1 and Position 2. The measured wind conditions were reported in [1] and [2], and represent the current wind climate on site. Wind conditions were also reported for two additional sites, Position 3 and Position 4. The data for these two points were derived from Position 1 and Position 2 and a WRF model map of the wind climate on site. As the WRF model does not take into account the existence of the Arkona and Wikinger wind farm, it is suspected that the derived wind climate may be slightly biased.

Methodology

EMD has customized WRF model runs for the Baltic sea area, using a Fitch [3] scheme to introduce the wake energy drain from the surrounding wind turbines. This is done for four scenarios: A baseline scenario 1 with no wind turbines, similar to the original WRF model, scenario 2, with the currently operating wind farm, and two additional future scenarios with several planned wind farms.

Based on these WRF models, EMD has quantified the relative wind speed and turbulence changes caused by surrounding wind farms. These wind speed changes are used to reassess the wind speed distribution at Position 3 and 4 and to assess the wind speed distribution for all four positions for two future scenarios.

The turbulence changes are used together with the speed changes to modify the reported turbulence intensity model for the Energy Island Baltic Sea.

All other site parameters are expected to be unchanged or insignificantly affected by the surrounding wind farms. Due to the nature of wind turbine wakes, which taper off at wind speeds exceeding rated power, extreme wind site parameters are not influenced by surrounding wind turbines.

Results

Revised wind distributions for Position 3 and 4 as well as future scenarios wind distributions for Position 1-4 are presented as well as a revised turbulence model for position 3.

20-year time series are provided for all four positions for scenario 2, 3 and 4.

Tiff files are provided with relative difference in wind speed and turbulence for the wind farm zone.

Revised site condition parameters are summarized in Table 1. Only data at 150 m are considered.

Please note that the methodology used for calculating the wake impact on the WRF model is not exhaustively validated and the results are not covered by the IEC standard used for the site wind conditions assessment. However, the WRF modelling setup and wind farm scheme is broadly used in the industry and academia.

Table 1. Summary tables of Site Wind Condition parameters at the four selected positions on the Baltic Sea Energy Island OWF zone. All values refer to 150 m height above sea level (ASL) and are based on 1 (Position 1 and 3) or 2 years (Position 2 and 4) of onsite measurements adjusted for the impact of wind turbines. ***Numbers in bold include WRF modelled wake effects, not-bold numbers are from the site wind conditions assessment****. The turbulence parameters in bracket is the alternative turbulence model, suggested for a limited wind direction interval (scenario 2: sector 7-8, scenario 3: sector 7-9)*

SCENARIO 2	POSITION 1	POSITION 2	POSITION 3	POSITION 4
Mean wind speed	9.92 m/s	9.94 m/s	**9.68 m/s**	**9.98 m/s**
Weibull distribution, A parameter (scale)	11.20 m/s	11.22 m/s	**10.93 m/s**	**11.27 m/s**
Weibull distribution, k parameter (shape)	2.18	2.20	**2.16**	**2.19**
Turbulence intensity mean value (TI_{μ}) at a 10-min average wind speed of 15m/s*	4.3%	4.3%	4.3% **(6.7%)**	4.3%
Turbulence intensity standard deviation (TI_{σ}) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0% **(2.7%)**	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	6.9%	6.9%	6.9% **(10.1%)**	6.9%

SCENARIO 3	POSITION 1	POSITION 2	POSITION 3	POSITION 4
Mean wind speed	**9.65 m/s**	**9.88 m/s**	**9.15 m/s**	**9.90 m/s**
Weibull distribution, A parameter (scale)	**10.89 m/s**	**11.16 m/s**	**10.33 m/s**	**11.18 m/s**
Weibull distribution, k parameter (shape)	**2.17**	**2.19**	**2.11**	**2.19**
Turbulence intensity mean value (TI_μ) at a 10-min average wind speed of 15m/s*	4.3%	4.3%	4.3% **(6.9%)**	4.3%
Turbulence intensity standard deviation (TI_σ) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0% **(2.7%)**	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	6.9%	6.9%	6.9% **(10.3%)**	6.9%

SCENARIO 4	POSITION 1	POSITION 2	POSITION 3	POSITION 4
Mean wind speed	**9.57 m/s**	**9.80 m/s**	**9.01 m/s**	**9.80 m/s**
Weibull distribution, A parameter (scale)	**10.81 m/s**	**11.06 m/s**	**10.17 m/s**	**11.07 m/s**
Weibull distribution, k parameter (shape)	**2.16**	**2.17**	**1.83**	**2.17**
Turbulence intensity mean value (TI_μ) at a 10-min average wind speed of 15m/s*	4.3%	4.3%	4.3% **(6.9%)**	4.3%
Turbulence intensity standard deviation (TI_σ) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0% **(2.7%)**	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	6.9%	6.9%	6.9% **(10.3%)**	6.9%

*Turbulence values at other wind speeds can be found in Appendix A and B.

The datasets produced by this study are available in a data package prepared for Energinet.

Recommendations

The WRF model impact from wind farms include wake effect, yet in close proximity to wind farms the wake wind speed deficit may be better calculated with industry standard wake models.

The results of the WRF model study should be considered outside this proximity zone. The width of the proximity zone is not entirely clear, but likely spans 4-6 km.

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1 Introduction

EMD has submitted a wind conditions assessment for the Energy Island Baltic Sea [1], followed up by a revalidation study [2]. The site parameters were assesses in accordance to IEC61400-1 [4], IEC 61400-3-1 [5] and IEC 61400-15-1 CD [6].

Measurements on site were conducted on two locations, Position 1 and Position 2. The measured wind conditions were reported in [1] and [2] and represent the current wind climate on site. Wind conditions were also reported on two additional sites, Position 3 and Position 4. The data for these two positions were derived from Position 1 and Position 2 and a WRF model map of the wind climate on site. As the WRF model does not take into account the existence of the Arkona and Wikinger wind farm, it is suspected that the derived wind climate is incorrect.

The mentioned standards do not provide a method for taking into account neighbouring windfarms and while direct wake effect is well studied, there is no standardized method available for assessing the impact of wind farms on the mesoscale climate.

EMD suggests to explore the impact on the wind climate by running customized WRF models for the Baltic Sea wind farm zone using a Fitch [3] scheme to represent the impact from wind farms on the mesoscale climate.

As this approach is not exhaustively validated it must be considered indicative only.

2 WRF models

Customized WRF models have been run for four scenarios, representing different stages of wind farm build-up in the region.

The WRF model used is version 4.5 with ERA5 data as the boundary data.

The wind turbines are represented in the WRF model using a Fitch scheme [3] with TKE advection.

This model approach was verified by [7] were the wind speed deficit at FINO1-3 was successfully predicted.

As the objective is to explore the relative change in the relevant wind climate parameters due to the wind farm impact, a representative year is used as input data. This reduces the calculation time while to a sufficient degree maintaining the correct wind speed level and direction distribution.

The criteria for being representative is that the windiness index (production output index) must be close to unity and the wind direction distribution should be close to the long-term distribution. Windiness index is preferred to wind speed index as this ensure that the wind speed distribution in the range producing wakes is representative.

A twenty-year period, 2003 to 2022, of EMD-WRF Europe+ data was considered. From this period, 2018 to 2022 was excluded as the first surrounding wind farms, Arkona and Wikinger were built at this time. From the rest, 2004 was selected as representative with a windiness index of 100.9 and a direction distribution close to the 20-year average (Figure 1).

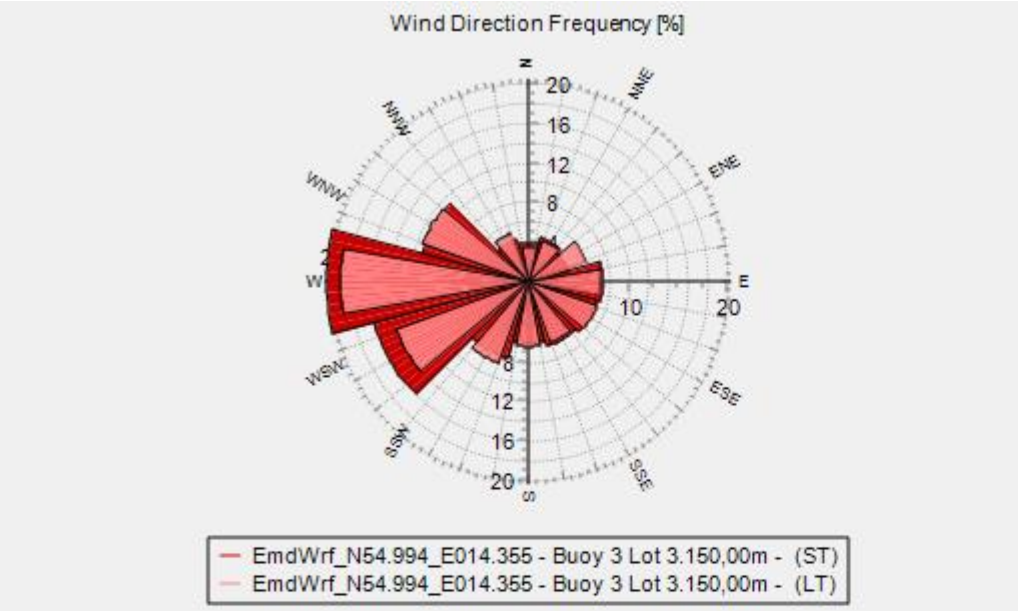

Figure 1. Direction distribution of 2004 (dark red) compared to the 20-year direction distribution (light red).

The WRF run is based on a domain of 300 by 300 km and produces a grid of time series with 1 km resolution, centred on the Energy Island Baltic Sea wind farm zone.

The temporal resolution of the output time series is 1 hour (internal model steps are of the order of seconds to ensure numerical stability).

3 WRF Scenarios

Plans exists for several wind farms near Energy Island Baltic Sea. These are presented in Figure 2 and Table 2.

Scenario 1 is the baseline scenario. This represents the situation without any wind turbines and is comparable to the model used to predict Position 3 and 4 in the reported wind conditions assessment. This scenario is also the baseline for the turbulence model.

Scenario 2 is the scenario during which measurements were made on Energy Island Baltic Sea. At this period of time the Arkona and the Wikinger wind farms were in operation. The wind speed measurements at Position 1 and 2 were under influence of these two wind farms.

Scenario 3 is a near future scenario which includes the wind farms Arkona Eolus, Triton+Skåne, Windanker, Baltic eagle and Arcadis Ost.

Scenario 4 is a far future scenario which includes O-2.2 and the four segments of Orlen.

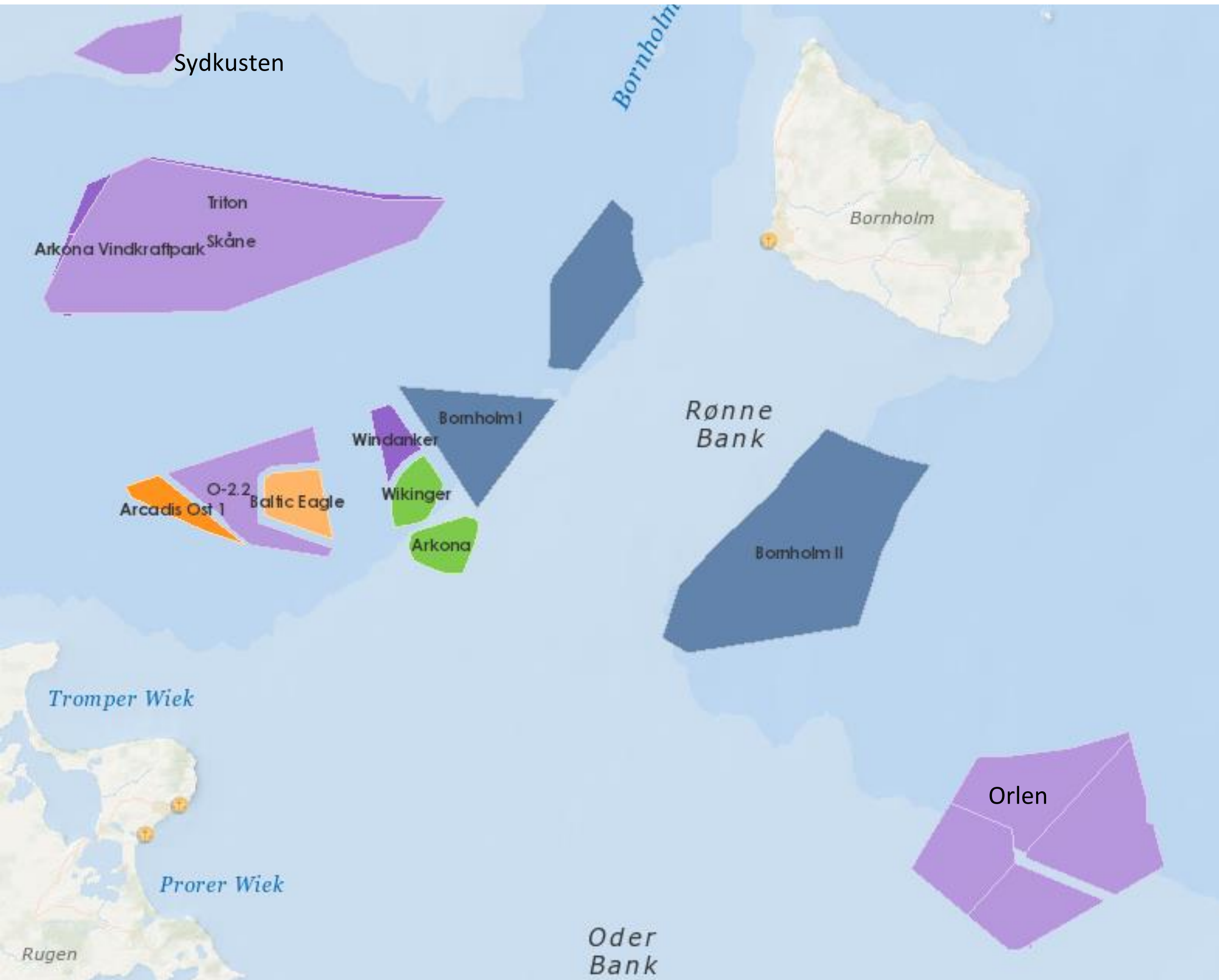

Figure 2. Operating and planned wind farms near Energy Island Baltic Sea (dark blue). (Source: 4C Offshore [8]

Table 2. List of wind farms and the scenarios in which they are included.

NAME	POWER, MW	POWER/UNIT, MW	UNITS	STATUS	SCENARIO 2	SCENARIO 3	SCENARIO 4
Arkona	378	6.3	60	Operating	Y	Y	Y
Wikinger	350	5	70	Operating	Y	Y	Y
O-2.2	1.000	20	50	Early planning	N	N	Y
Arkona Eolus	1.400	20	70	Consent Application Submitted	N	Y	Y
Triton + Skåne	1.500	20	75	Consent Application Submitted	N	Y	Y
Orlen N	629	20	32	Concept/Early Planning	N	N	Y
Orlen E	738	20	37	Concept/Early Planning	N	N	Y
Orlen S	412	20	21	Concept/Early Planning	N	N	Y
Orlen W	456	20	23	Concept/Early Planning	N	N	Y
Sydkusten	500	20	25	Withdrawn	N	N	N
Windanker	315	15	21	Consent Application Submitted	N	Y	Y
Baltic Eagle	470	9.4	50	Under Construction	N	Y	Y
Arcadis Ost	254	9.4	27	Partial Generation/Under Construction	N	Y	Y

For the wind farms in operation the actual turbine type and size is used including the turbine specific thrust curve.

For planned wind farms, the publicized data are used where available and otherwise assumed based on planned installed power. Future wind farms are assumed using 20 MW turbines. Thrust curves for future wind farms is generic based on typical large turbine thrust curves (Figure 3).

The scenarios are presented on maps (Figure 4 - Figure 6).

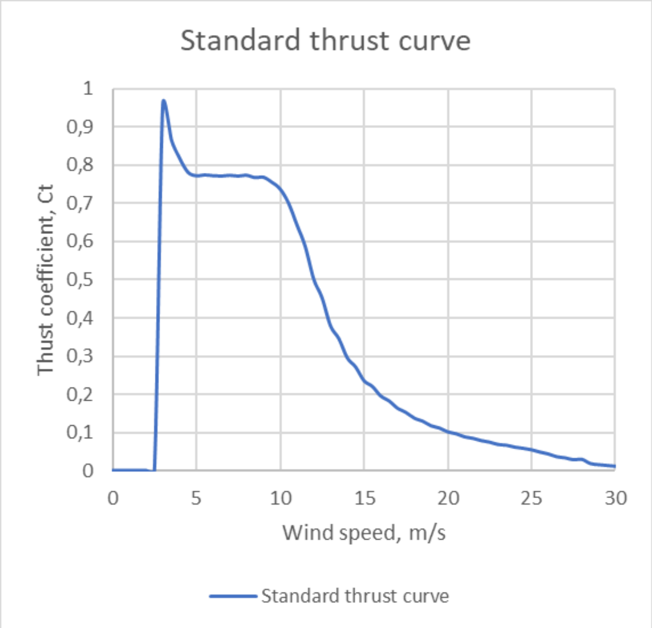

Figure 3. Standard thrust curve, to be used where wind turbine type is not known.

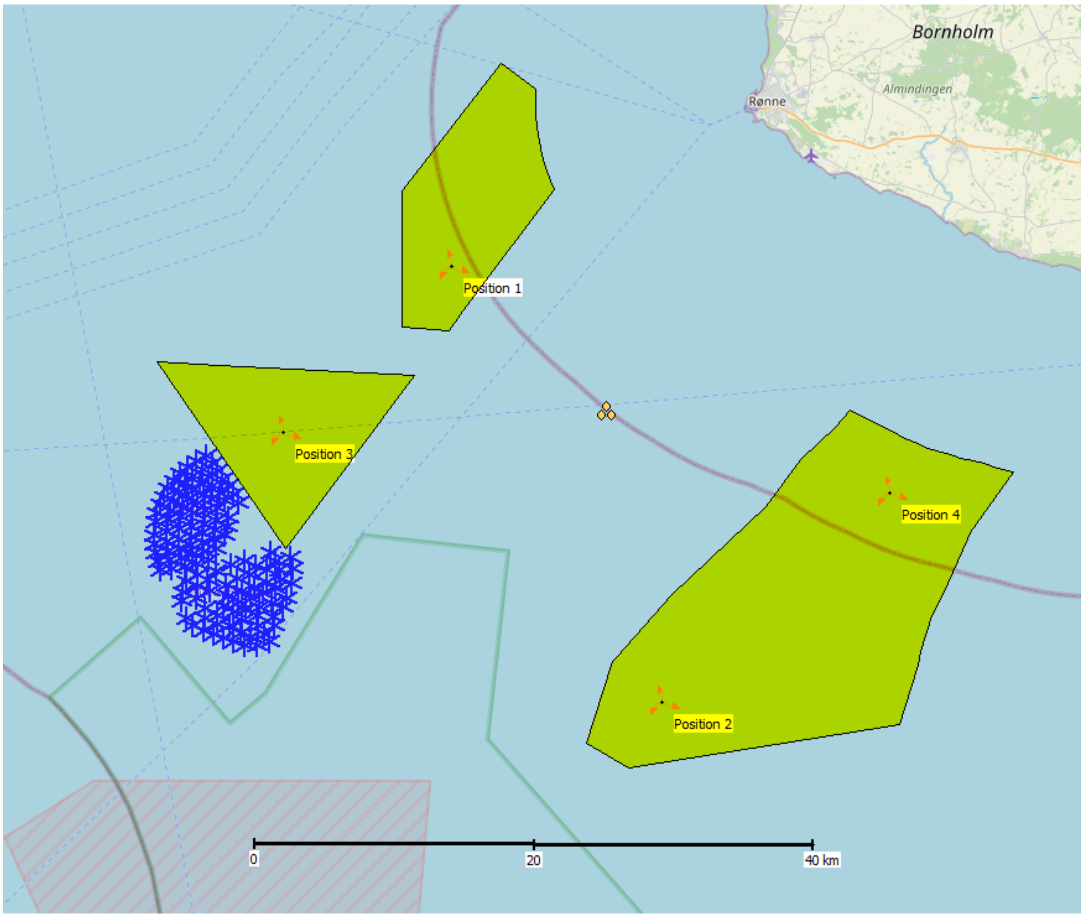

Figure 4. Scenario 2

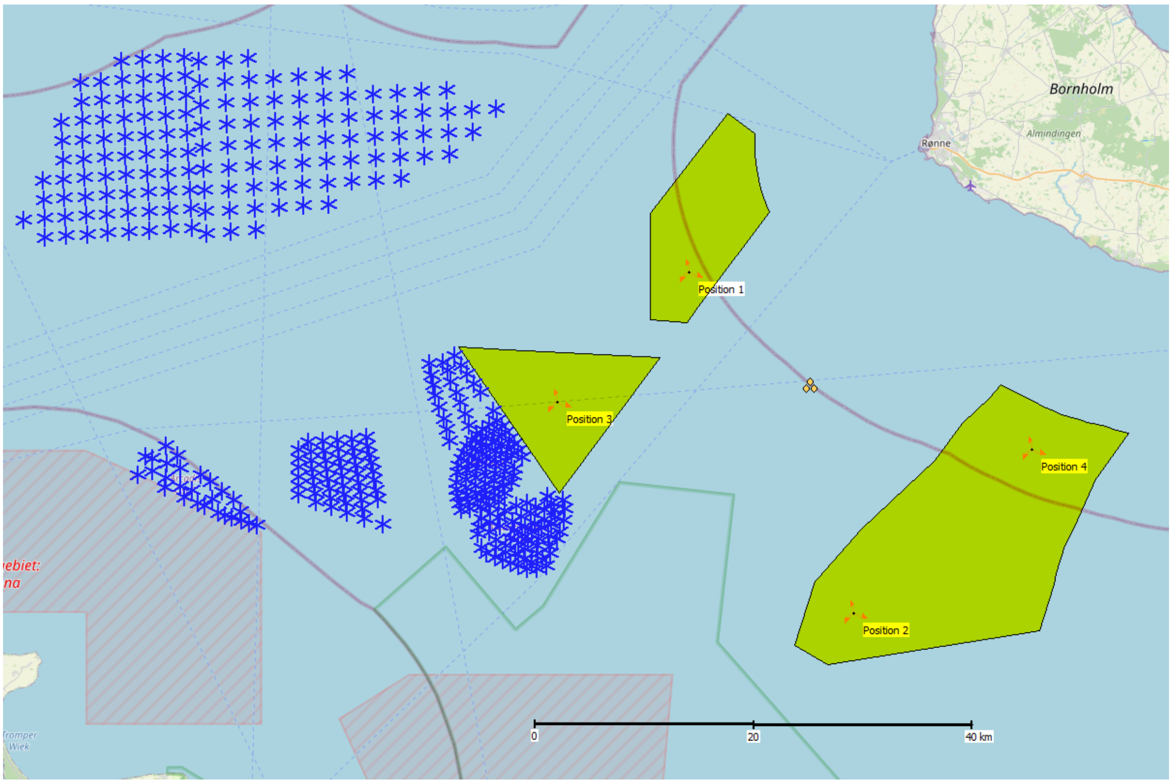

Figure 5. Scenario 3

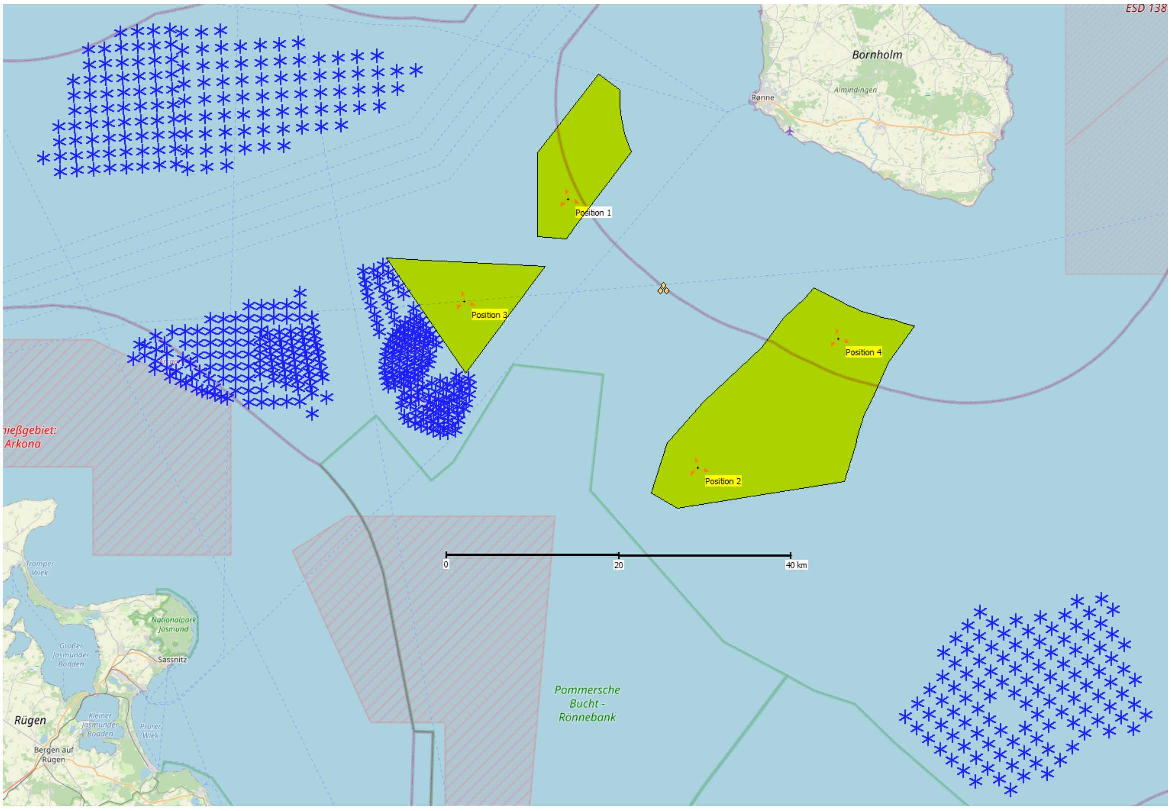

Figure 6. Scenario 4

4 Revised wind speed distribution

4.1 Wind speed ratio maps

The relative change in wind speed between scenarios are presented below. The ratio is on the average wind speed at 150 m height AMSL. The wind speed reduction in direct wake wind directions will be higher. As the WRF model setup is intended for modelling wind farm wakes and not intra-park individual turbines wakes, conditions inside wind farms should be disregarded.

The baseline comparison is between the wind farm scenarios and the WRF model basis used in the wind conditions assessment (without influence from wind farms).

The ratio between scenario 2 and scenario 1 is presented in Figure 7.

The ratio between scenario 3 and scenario 1 is presented in Figure 8.

The ratio between scenario 4 and scenario 1 is presented in Figure 9.

Comparisons to the wind conditions during which measurements were made at Position 1 and 2 uses scenario 2 as base line. Here is no notable effect from the Arkona and Wikinger wind farm as they were operating at the time.

The ratio between scenario 3 and scenario 2 is presented in Figure 10.

The ratio between scenario 4 and scenario 2 is presented in Figure 11.

The maps are provided as deliverables in Tiff format.

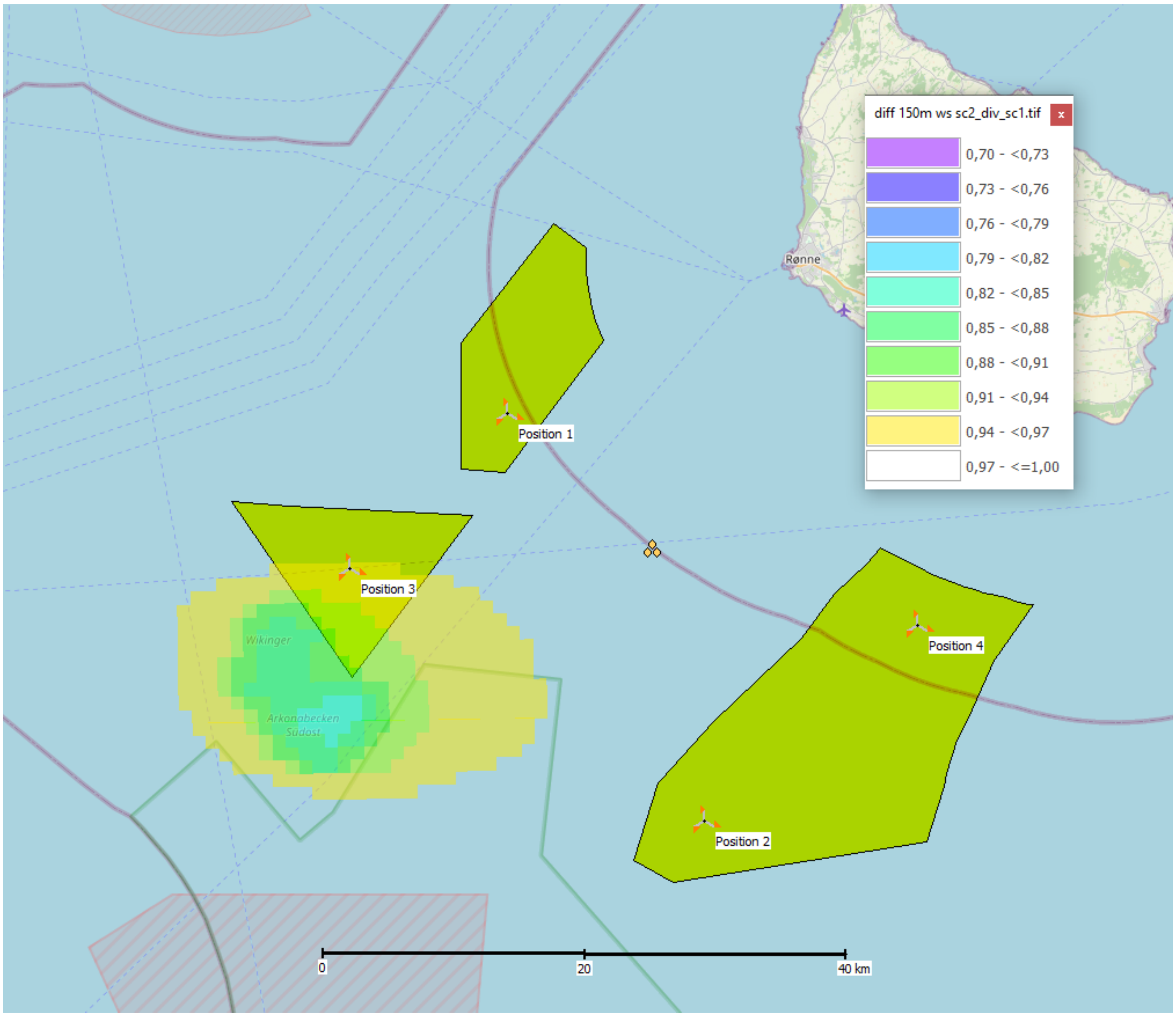

Figure 7. Wind speed scenario 2 divided by scenario 1.

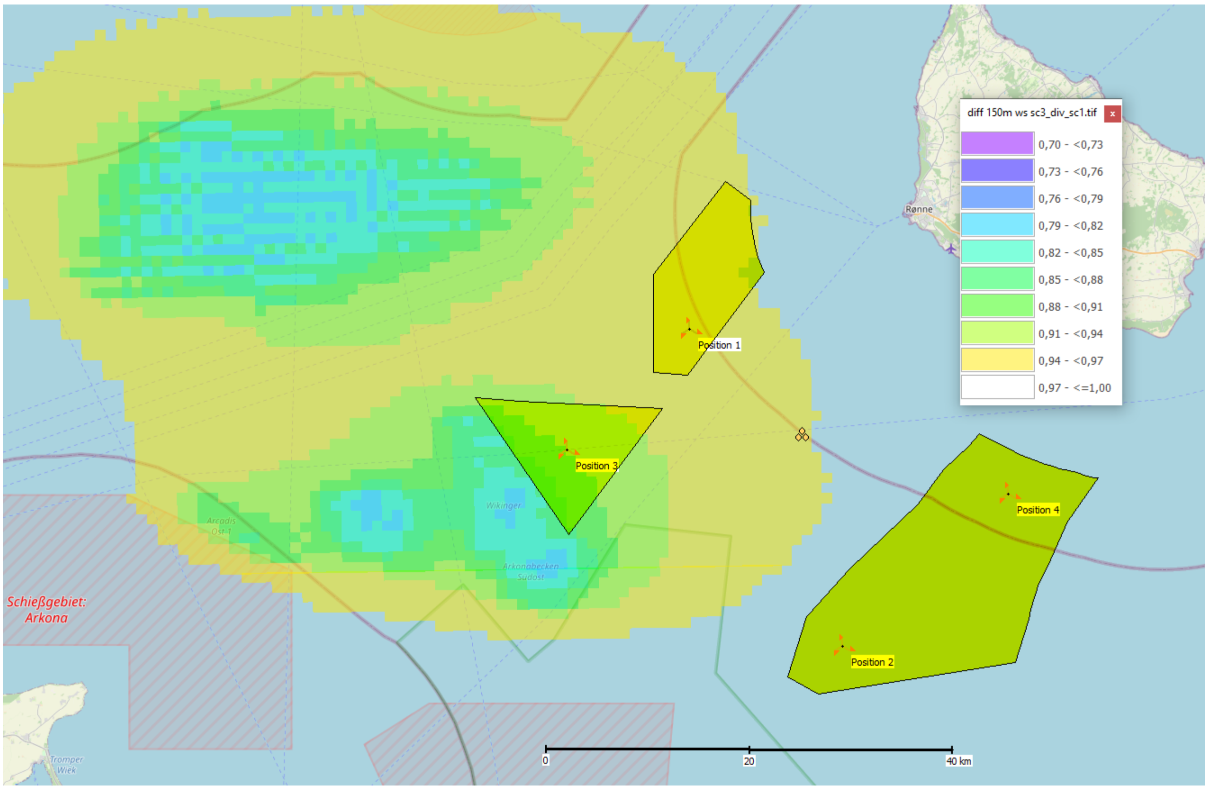

Figure 8. Wind speed scenario 3 divided by scenario 1.

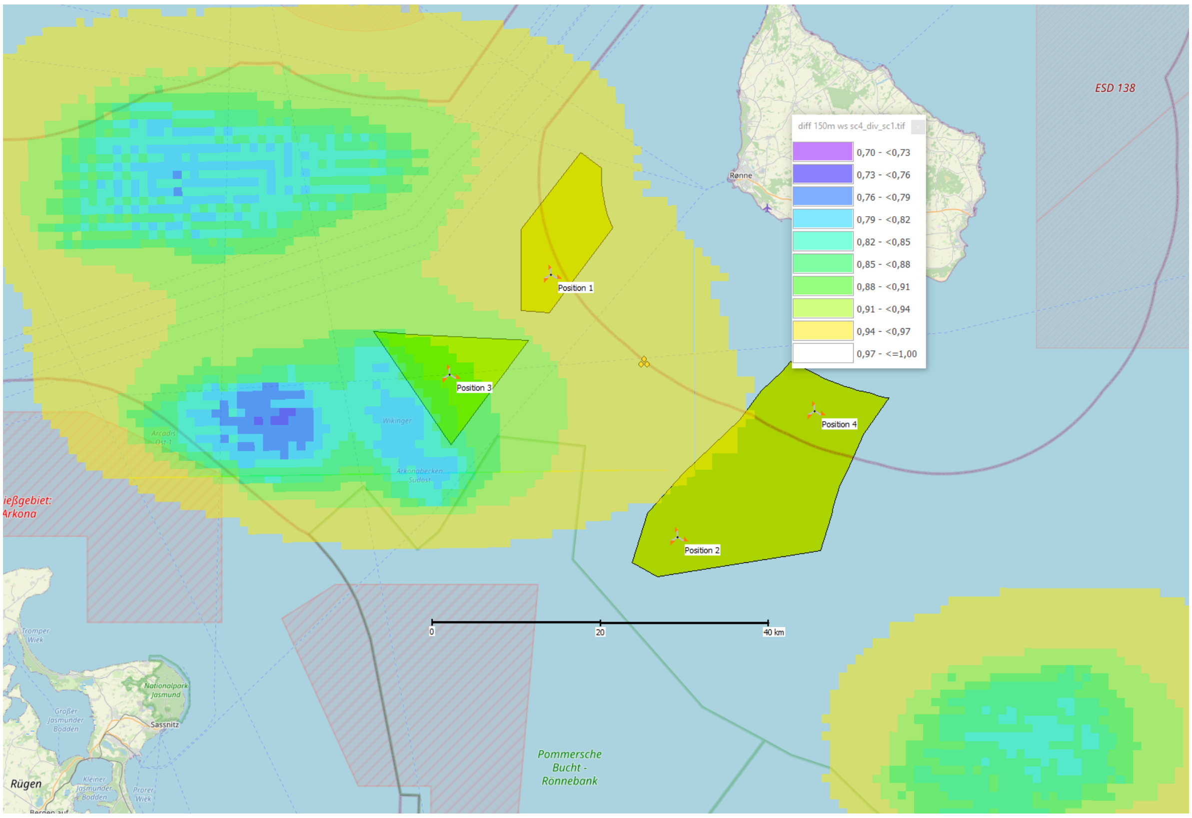

Figure 9. Wind speed scenario 4 divided by scenario 1.

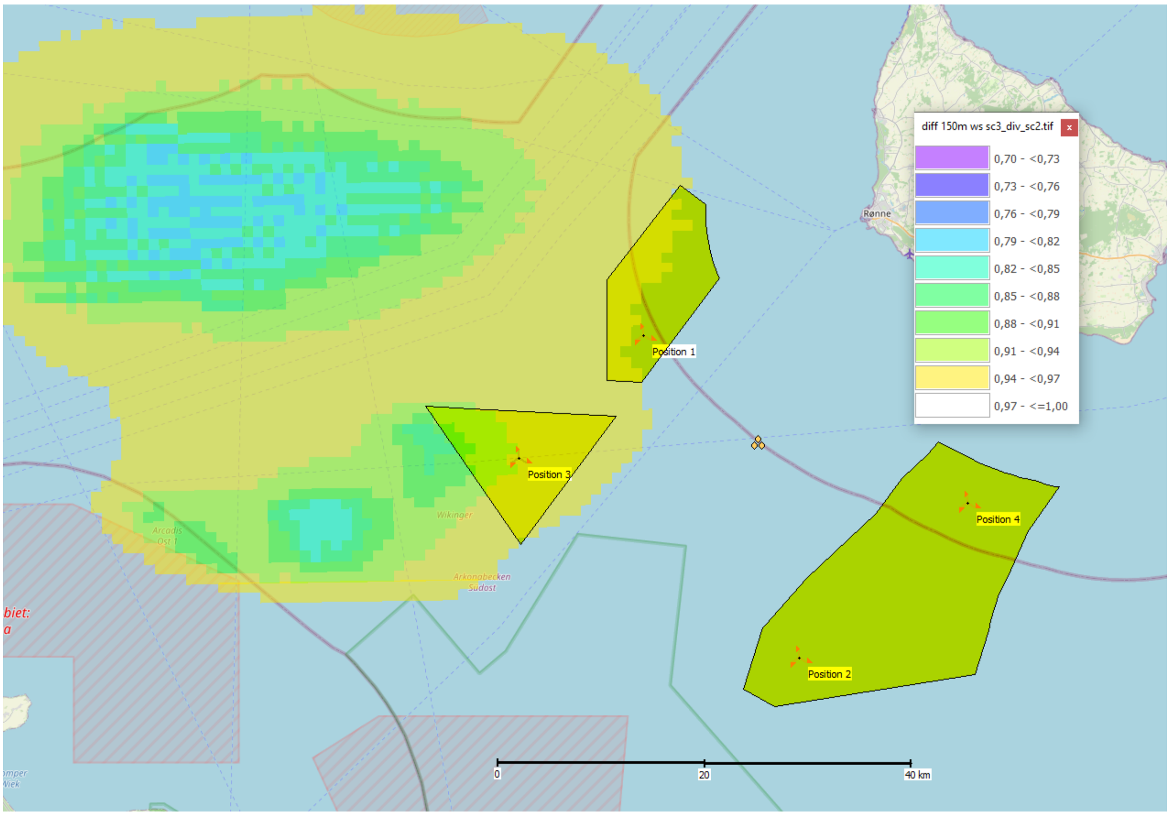

Figure 10. Wind speed scenario 3 divided by scenario 2.

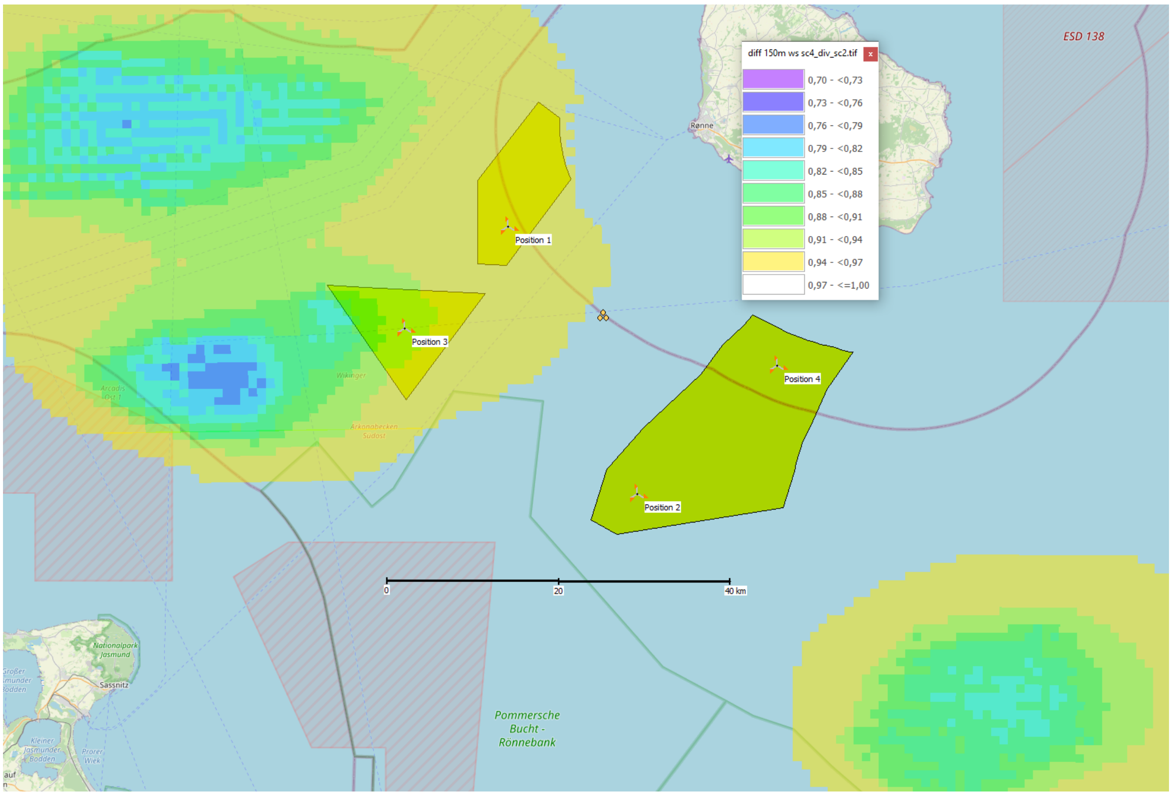

Figure 11. Wind speed scenario 4 divided by scenario 2.

4.2 Correction of wind speed at reported positions

The impact on wind speed can be applied to the time series and wind distributions reported in the site wind conditions assessment.

EMD investigated different correction methods. In the example presented below (Position 1: scenario 3 divided by scenario 2) is demonstrated sector-wise correction in 1 m/s bins and as wind speed independent correction (Figure 12).

It is clear that the wind speed binning suffers from noise, especially below 5 m/s and is highly irregular. On the other hand, it is also easy to recognize the influence of the thrust curve with high impact at mid-range wind speeds, but little to no effect at high wind speed and a very confused picture below cut-in. A wind speed independent correction, demonstrated for the three sectors with the highest impact, will underpredict the impact at mid-range wind speed and overpredict the correction at high wind speed.

A robust compromise is to derive and apply a constant in the correction for the interval 5 to 20 m/s only.

For the turbulence analysis this interval is further reduced to 5 to 15 m/s.

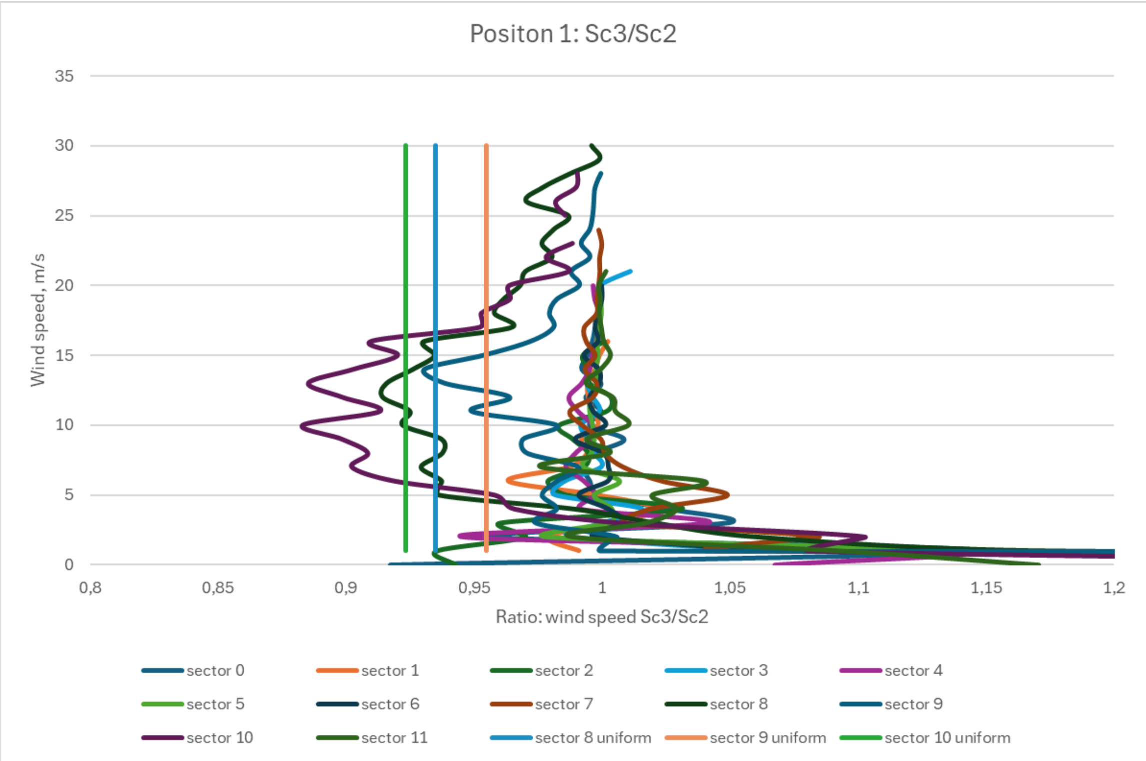

Figure 12. Wind speed correction at Position 1 for scenario 3 /scenario 2. Wind speed binned and wind speed independent.

The resulting sector-wise correction factors are presented below for Position 1 and Position 2.

Table 3. Wind speed ratios by sector for Position 1 and Position 2. Corrections of at least 3% are highlighted. Corrections are made in all sectors.

	POSITION 1		POSITION 2	
SECTOR	WS SC3/SC2	WS SC4/SC2	WS SC3/SC2	WS SC4/SC2
0	1.00	0.99	1.00	1.00
1	0.99	0.99	1.00	1.00
2	0.99	0.99	1.00	1.00
3	0.99	0.99	0.99	1.00
4	0.99	0.98	1.00	0.93
5	1.00	**0.97**	1.00	0.98
6	1.00	1.01	1.00	1.00
7	1.00	1.00	1.00	1.00
8	**0.94**	**0.90**	1.00	1.00
9	**0.97**	**0.96**	1.00	0.99
10	**0.91**	**0.91**	**0.96**	**0.94**
11	1.00	1.00	0.99	0.99

Since Position 3 and 4 were derived from Position 1 and 2 using a wind speed scale factor method (A parameter scaling) based on the original WRF model, the Position 3 and 4 time series must be recreated from Position 1 and 2 using the new WRF data.

Table 4 presents the new correction factors for Position 3 from Position 1 as well as the relative correction factors scenario 1 to the wind farm scenarios.

Table 5 presents the new correction factors for Position 4 from Position 2 as well as the relative correction factors scenario 1 to the wind farm scenarios.

Table 4. Wind speed ratios by sector for Position 3. Left set of ratios are new correction factors to recreate time series of data for Position 3. Right set of ratios are difference at Position 3 from undisturbed (reported) data and the wind farm impacted scenarios. Corrections of the right set of at least 3% are highlighted. Corrections are made in all sectors.

POSITION 3	RELATIVE TO POSITION 1, SCENARIO 2			RELATIVE TO POSITION 3, SCENARIO 1		
SECTOR	WS SC2/ POS1_SC2	WS SC3/ POS1_SC2	WS SC4/ POS1_SC2	WS SC2/SC1	WS SC3/SC1	WS SC4/SC1
0	0.95	0.95	0.95	0.99	0.99	0.98
1	0.96	0.95	0.95	0.99	0.98	0.98
2	1.01	1.00	1.00	1.00	0.98	0.98
3	1.04	1.03	1.03	0.99	0.98	0.98
4	1.00	0.99	0.97	0.99	0.98	**0.96**
5	0.99	0.99	0.98	1.00	0.99	0.98
6	0.92	0.91	0.92	**0.91**	**0.90**	**0.91**
7	0.91	0.91	0.91	**0.85**	**0.85**	**0.85**
8	0.92	0.85	0.83	**0.89**	**0.82**	**0.80**
9	0.99	0.87	0.82	0.99	**0.86**	**0.81**
10	0.99	0.87	0.88	1.00	**0.87**	**0.87**
11	1.01	0.94	0.94	0.99	**0.92**	**0.92**

Table 5. Wind speed ratios by sector for Position 4. Left set of ratios are new correction factors to recreate time series of data for Position 4. Right set of ratios are difference at Position 4 from undisturbed (reported) data and the wind farm impacted scenarios. Corrections of the right set of at least 3% are highlighted. Corrections are made in all sectors.

POSITION 4	RELATIVE TO POSITION 2, SCENARIO 2			RELATIVE TO POSITION 4, SCENARIO 1		
SECTOR	WS SC2/ POS2_SC2	WS SC3/ POS2_SC2	WS SC4/ POS2_SC2	WS SC2/SC1	WS SC3/SC1	WS SC4/SC1
0	0.98	0.99	0.98	1.01	1.02	1.01
1	1.02	1.02	1.01	1.00	1.00	0.99
2	1.02	1.02	1.01	1.00	1.00	0.99
3	0.98	0.97	0.97	1.00	1.00	1.00
4	0.98	0.98	0.97	1.00	1.00	0.99
5	0.99	0.99	0.90	1.00	1.00	**0.92**
6	0.98	0.98	0.96	1.00	1.00	0.99
7	1.00	1.00	1.00	1.00	1.00	1.00
8	1.01	1.02	1.02	1.00	1.00	1.00
9	1.01	0.99	0.97	**0.97**	**0.95**	**0.93**
10	1.05	1.01	1.01	1.00	**0.97**	**0.96**
11	0.97	0.98	0.98	1.00	1.02	1.02

The listed corrections are applied to the long-term corrected time series at Position 1 and Position 2 in the wind speed interval 5 to 20 m/s to derive new long term time series for all four positions in the relevant scenarios.

The time series are deliverables.

New wind distributions are derived from the time series and are presented in the following tables.

The change in mean wind speed across the scenarios are presented in Table 6.

Table 6. Mean wind speed for each position in each scenario. Wind speed is the Weibull derived mean wind speed. The increase in wind speed at Position 4 from reported scenario to scenario 2 is due to noise in the model. No increase in wind speed is expected due to added wind turbines.

Mean wind speed, m/s	Reported scenario [2]	Scenario 2	Scenario 3	Scenario 4
Position 1	9.92	9.92	9.65	9.57
Position 2	9.94	9.94	9.88	9.80
Position 3	9.96	9.68	9.15	9.01
Position 4	9.97	9.98	9.90	9.80

4.2.1 Scenario 2 wind distributions

This is the scenario during which measurement campaign was running.

Table 7. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 1 – scenario 2. Wind speeds are derived from the Weibull distribution.

POSITION 1 – SCENARIO 2 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.20	2.184	100.00	9.92
0-N	7.98	1.854	3.58	7.08
1-NNE	9.24	1.910	4.51	8.19
2-ENE	10.48	2.200	5.96	9.28
3-E	10.56	2.196	7.29	9.35
4-ESE	10.00	2.370	7.35	8.87
5-SSE	9.73	2.337	6.37	8.62
6-S	10.68	2.129	7.22	9.46
7-SSW	11.38	2.329	8.68	10.08
8-WSW	13.09	2.480	13.50	11.62
9-W	13.01	2.462	18.89	11.54
10-WNW	11.16	2.212	11.45	9.89
11-NNW	9.24	2.067	5.21	8.19

Table 8. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 2 – scenario 2. Wind speeds are derived from the Weibull distribution.

POSITION 2 – SCENARIO 2 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.22	2.197	100.00	9.94
0-N	8.28	1.878	3.59	7.35
1-NNE	8.92	1.874	3.81	7.92
2-ENE	11.12	2.221	7.09	9.85
3-E	10.87	2.480	7.70	9.64
4-ESE	9.95	2.614	6.45	8.84
5-SSE	9.77	2.306	6.50	8.65
6-S	10.75	2.177	7.17	9.52
7-SSW	12.23	2.483	9.26	10.85
8-WSW	12.66	2.596	12.97	11.24
9-W	12.82	2.247	18.29	11.36
10-WNW	10.81	2.099	11.77	9.57
11-NNW	9.39	2.041	5.39	8.32

Table 9. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 1, moved to Position 3 – scenario 2. Wind speeds are derived from the Weibull distribution.

POSITION 3 - SCENARIO 2 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	10.93	2.158	100.00	9.68
0-N	7.60	1.834	3.58	6.75
1-NNE	8.90	1.918	4.51	7.89
2-ENE	10.56	2.199	5.95	9.35
3-E	11.05	2.222	7.29	9.79
4-ESE	10.03	2.376	7.36	8.89
5-SSE	9.68	2.335	6.37	8.57
6-S	9.89	2.044	7.22	8.76
7-SSW	10.46	2.235	8.67	9.26
8-WSW	12.14	2.314	13.48	10.76
9-W	12.94	2.457	18.90	11.48
10-WNW	11.08	2.212	11.46	9.82
11-NNW	9.39	2.065	5.22	8.32

Table 10. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 2, moved to Position 4 – scenario 2. Wind speeds are derived from the Weibull distribution.

POSITION 4 – SCENARIO 2 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.27	2.192	100.00	9.98
0-N	8.14	1.873	3.59	7.22
1-NNE	9.08	1.837	3.81	8.07
2-ENE	11.35	2.217	7.09	10.05
3-E	10.61	2.491	7.70	9.41
4-ESE	9.74	2.608	6.46	8.65
5-SSE	9.65	2.305	6.50	8.55
6-S	10.48	2.164	7.17	9.28
7-SSW	12.16	2.494	9.25	10.79
8-WSW	12.84	2.607	12.97	11.40
9-W	12.96	2.273	18.28	11.48
10-WNW	11.34	2.138	11.79	10.05
11-NNW	9.14	2.042	5.39	8.10

4.2.2 Scenario 3 wind distributions

This is the near future scenario.

Table 11. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 1 – corrected to scenario 3. Wind speeds are derived from the Weibull distribution.

POSITION 1 – SCENARIO 3 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	10.89	2.165	100.00	9.65
0-N	7.95	1.854	3.58	7.06
1-NNE	9.18	1.921	4.51	8.14
2-ENE	10.38	2.190	5.95	9.19
3-E	10.52	2.202	7.29	9.32
4-ESE	9.93	2.365	7.36	8.80
5-SSE	9.72	2.339	6.37	8.61
6-S	10.63	2.119	7.22	9.41
7-SSW	11.41	2.335	8.67	10.11
8-WSW	12.34	2.368	13.48	10.94
9-W	12.60	2.393	18.90	11.17
10-WNW	10.19	2.116	11.46	9.02
11-NNW	9.28	2.071	5.22	8.22

Table 12. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 2 – corrected to scenario 3. Wind speeds are derived from the Weibull distribution.

POSITION 2 – SCENARIO 3 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.16	2.188	100.00	9.88
0-N	8.28	1.880	3.59	7.35
1-NNE	8.88	1.872	3.81	7.88
2-ENE	11.14	2.222	7.09	9.87
3-E	10.81	2.480	7.70	9.59
4-ESE	9.91	2.618	6.46	8.81
5-SSE	9.74	2.307	6.50	8.63
6-S	10.76	2.178	7.17	9.53
7-SSW	12.23	2.483	9.25	10.85
8-WSW	12.66	2.599	12.97	11.25
9-W	12.81	2.243	18.28	11.35
10-WNW	10.39	2.058	11.79	9.20
11-NNW	9.34	2.043	5.39	8.28

Table 13. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 1, moved to Position 3 – scenario 3. Wind speeds are derived from the Weibull distribution.

POSITION 3 – SCENARIO 3 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	10.33	2.108	100.00	9.15
0-N	7.57	1.827	3.58	6.72
1-NNE	8.80	1.913	4.51	7.81
2-ENE	10.43	2.188	5.95	9.23
3-E	10.93	2.216	7.29	9.68
4-ESE	9.93	2.366	7.36	8.80
5-SSE	9.59	2.341	6.37	8.50
6-S	9.78	2.039	7.22	8.66
7-SSW	10.39	2.227	8.67	9.20
8-WSW	11.40	2.178	13.48	10.09
9-W	11.50	2.214	18.90	10.19
10-WNW	9.83	2.076	11.46	8.71
11-NNW	8.74	2.050	5.22	7.74

Table 14. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 2, moved to Position 4 – scenario 3. Wind speeds are derived from the Weibull distribution.

POSITION 4 – SCENARIO 3 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.18	2.187	100.00	9.90
0-N	8.16	1.870	3.59	7.25
1-NNE	9.07	1.839	3.81	8.06
2-ENE	11.32	2.216	7.09	10.02
3-E	10.60	2.494	7.70	9.41
4-ESE	9.73	2.605	6.46	8.64
5-SSE	9.63	2.306	6.50	8.53
6-S	10.49	2.165	7.17	9.29
7-SSW	12.17	2.494	9.25	10.79
8-WSW	12.89	2.615	12.97	11.45
9-W	12.70	2.234	18.28	11.24
10-WNW	10.93	2.101	11.79	9.68
11-NNW	9.24	2.052	5.39	8.18

4.2.3 Scenario 4 wind distributions

This is the far future scenario.

Table 15. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 1 – corrected to scenario 4. Wind speeds are derived from the Weibull distribution.

POSITION 1 – SCENARIO 4 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	10.81	2.158	100.00	9.57
0-N	7.92	1.857	3.58	7.03
1-NNE	9.18	1.920	4.51	8.14
2-ENE	10.41	2.194	5.95	9.22
3-E	10.52	2.205	7.29	9.31
4-ESE	9.79	2.353	7.36	8.68
5-SSE	9.49	2.337	6.37	8.41
6-S	10.74	2.139	7.22	9.51
7-SSW	11.41	2.335	8.67	10.11
8-WSW	11.92	2.294	13.48	10.56
9-W	12.54	2.383	18.90	11.11
10-WNW	10.18	2.117	11.46	9.02
11-NNW	9.28	2.073	5.22	8.22

Table 16. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 2 – corrected to scenario 4. Wind speeds are derived from the Weibull distribution.

POSITION 2 – SCENARIO 4 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.06	2.172	100.00	9.80
0-N	8.29	1.880	3.59	7.36
1-NNE	8.88	1.871	3.81	7.88
2-ENE	11.11	2.219	7.09	9.84
3-E	10.86	2.477	7.70	9.64
4-ESE	9.24	2.596	6.46	8.21
5-SSE	9.54	2.303	6.50	8.46
6-S	10.75	2.176	7.17	9.52
7-SSW	12.22	2.484	9.25	10.84
8-WSW	12.67	2.602	12.97	11.26
9-W	12.70	2.232	18.28	11.25
10-WNW	10.21	2.032	11.79	9.04
11-NNW	9.30	2.043	5.39	8.24

Table 17. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 1, moved to Position 3 – scenario 4. Wind speeds are derived from the Weibull distribution.

POSITION 3 – SCENARIO 4 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	10.17	2.089	100.00	9.01
0-N	7.53	1.825	3.58	6.69
1-NNE	8.76	1.905	4.51	7.77
2-ENE	10.43	2.190	5.95	9.24
3-E	10.94	2.214	7.29	9.69
4-ESE	9.70	2.345	7.36	8.60
5-SSE	9.57	2.338	6.37	8.48
6-S	9.84	2.043	7.22	8.72
7-SSW	10.41	2.230	8.67	9.22
8-WSW	11.14	2.133	13.48	9.87
9-W	10.88	2.094	18.90	9.64
10-WNW	9.87	2.082	11.46	8.74
11-NNW	8.73	2.051	5.22	7.73

Table 18. Weibull distribution parameters based on long-term corrected LIDAR data at 150 m ASL Position 2, moved to Position 4 – scenario 4. Wind speeds are derived from the Weibull distribution.

POSITION 4 – SCENARIO 4 SECTOR	A PARAMETER [M/S]	K PARAMETER [-]	FREQUENCY [%]	MEAN WIND SPEED [M/S]
Mean	11.07	2.172	100.00	9.80
0-N	8.14	1.872	3.59	7.23
1-NNE	9.03	1.837	3.81	8.02
2-ENE	11.26	2.211	7.09	9.98
3-E	10.59	2.493	7.70	9.40
4-ESE	9.68	2.604	6.46	8.60
5-SSE	8.83	2.296	6.50	7.82
6-S	10.34	2.164	7.17	9.16
7-SSW	12.17	2.494	9.25	10.79
8-WSW	12.89	2.614	12.97	11.45
9-W	12.52	2.208	18.28	11.09
10-WNW	10.89	2.100	11.79	9.64
11-NNW	9.24	2.053	5.39	8.19

5 Turbulence correction

5.1 Turbulence correction methodology

The WRF model scenarios are used to establish the key correction parameters for the affected wake sectors between the modelled build-out scenarios at the target positions. Key correction parameters are wind speed reduction/speed-up factor (f_u) and turbulence increase factor (f_σ). Where, the former will affect the wind speed and the latter the wind speed standard deviation (turbulence) at a specific wind speed. As the turbulence intensity (TI) is the ratio of standard deviation and wind speed, TI will have significant effects from both correction factors.

Wake effects of up-stream wind farms, i.e. wind speed reduction and turbulence increase, follow the signature of the thrust curve of the up-wind turbines. Typical thrust curves exhibit a close to constant thrust coefficient from around cut-in wind speed to around the wind speed where rated power is reached, typically between 10 to 15 m/s. At wind speeds above rated the thrust falls off proportional to u^{-2} . Given the numerical noise in each scenario we keep the model as simple as possible still capturing the important main effect according to the modelling principle of "Occams razor" [9]. Here, this leads to the following key simplifying assumptions:

- Below 5m/s and above 20m/s thrust and wake effects are not significant, and correction factors are set to equal one (no effect)
- Between 5m/s and 15m/s effects are modelled as constant factors both for wind speed reduction (f_u) and turbulence increase (f_σ)
- Between 15m/s and 20m/s we linearly step out the factors from their full at 15m/s value to unity at 20m/s
- Sectors with significant wake effects are identified and combined to a wake affected direction interval representing an integer number of 30 deg sectors
- A single wake corrected turbulence model is provided for scenarios/positions to replace the original ambient model in the defined wake affected sectors

Within the wind speed and direction interval where correction is applied the following model is adopted. The implicit assumption is that at any given flow situation the standard deviation (i.e. turbulence) remains constant across the area around a park (see e.g. [10]). The first component of the model is assuming that the wind speed deficit effect can be modelled as a local wind speed reduction factor only affecting wind speed (standard deviation is unaffected). The second component is assuming that the turbulence generation by upstream farm(s) can be modelled by a turbulence increase factor only affecting the standard deviation. The combined correction model leads to a corrected turbulence versus wind speed including both of the above model components.

5.2 Significant wake effect

An initial analysis of the ratio of sector-wise and wind speed binned sigma (standard deviation of wind speed) demonstrated a high level of noise in the data (Figure 13). As a result, the threshold for relevant correction was set high, at 10% increase in sigma. Only those sectors qualify to get an adjusted turbulence value.

The sigma ratios found are presented in Table 19 and Table 20

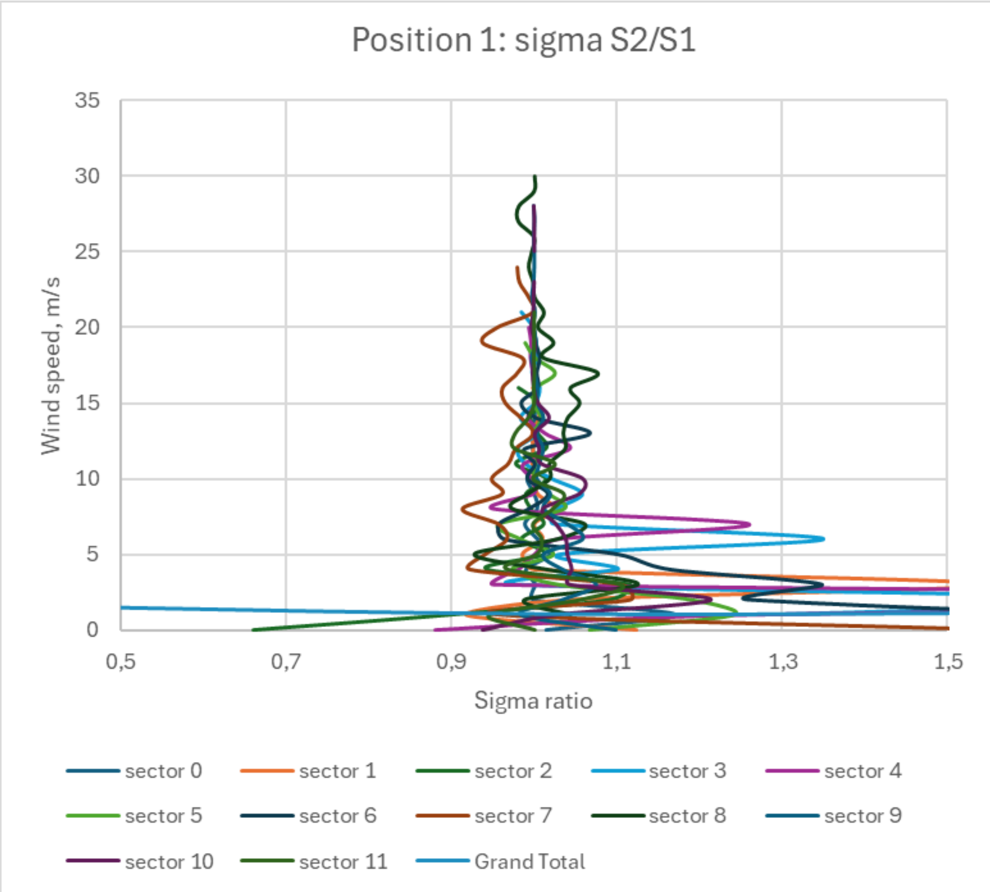

Figure 13. Ratio of sigma between scenario 2 and scenario 1 on Position 1. The ratio is both sector and wind speed binned.

Table 19. Ratio of sector-wise sigma in the wind speed interval 5-15 m/s, Position 1 and 2.

SIGMA RATIO	POSITON 1			POSITION 2		
SECTOR	σ SC2/SC1	σ SC3/SC1	σ SC4/SC1	σ SC2/SC1	σ SC3/SC1	σ SC4/SC1
0	1.00	0.99	1.00	1.00	1.03	1.02
1	0.99	1.01	1.02	1.01	1.01	1.03
2	1.01	1.01	0.99	0.99	0.99	0.99
3	1.02	1.00	1.01	1.00	1.00	0.97
4	0.99	1.00	0.98	0.99	1.00	0.91
5	0.99	0.98	0.99	1.00	1.00	1.04
6	1.00	1.01	1.02	0.99	0.99	1.00
7	0.98	0.97	0.96	1.01	1.01	1.02
8	1.03	1.01	1.02	0.99	0.99	0.99
9	1.01	0.98	1.01	0.99	0.98	0.97
10	1.00	1.04	1.04	1.04	1.02	1.03
11	1.00	1.07	1.06	1.01	1.02	1.03

Table 20. Ratio of sector-wise sigma in the wind speed interval 5-15 m/s, Position 3 and 4. Sectors above threshold are highlighted.

SIGMA RATIO	POSITON 3			POSITION 4		
SECTOR	σ SC2/SC1	σ SC3/SC1	σ SC4/SC1	σ SC2/SC1	σ SC3/SC1	σ SC4/SC1
0	1.03	1.04	1.05	1.04	1.05	1.05
1	0.93	0.93	0.94	0.99	1.00	0.99
2	1.00	1.01	1.00	1.00	1.00	1.00
3	1.02	1.02	1.02	1.00	1.02	1.02
4	1.03	1.02	0.98	1.05	1.05	1.01
5	0.96	0.97	0.99	1.01	1.02	0.96
6	1.01	1.00	1.00	1.03	1.03	1.08
7	**1.22**	**1.20**	**1.20**	1.01	1.00	1.00
8	**1.31**	**1.34**	**1.30**	0.99	0.98	0.98
9	1.04	**1.18**	**1.20**	0.95	0.93	0.92
10	1.00	1.06	1.07	1.03	1.04	1.05
11	0.99	1.05	1.05	1.02	1.04	1.05

Only Position 3, scenarios 2, 3 and 4 have sectors with ratio of sigma above threshold. The frequency weighted average of wind speed and sigma ratios are found for each scenario. Scenarios 3 and 4 are identical.

Table 21. Wind direction frequency weighted averages of wind speed and sigma ratios in the direction interval with sigma increase above threshold. Position 3

FREQUENCY WEIGHTED AVERAGES	POSITON 3		
SECTOR	SC2/SC1	SC3/SC1	SC4/SC1
Sector interval	7 – 8	7 – 9	7 -9
WS ratio 5-15 m/s (f_u)	0.88	0.84	0.84
σ ratio (f_σ)	1.28	1.24	1.24

The scenario 2 and 3 sigma ratio maps are presented below.

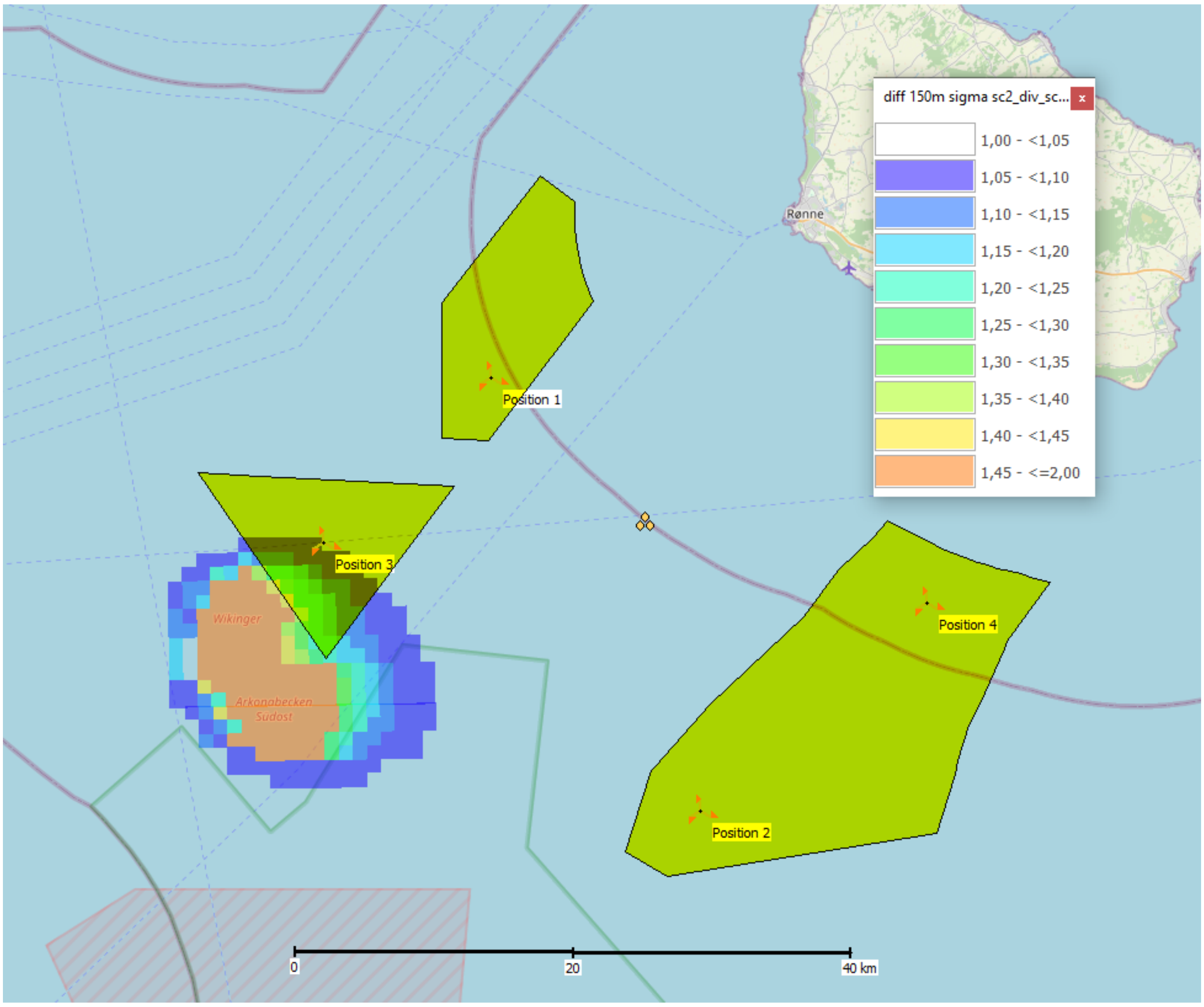

Figure 14. Ratio of average sigma, Scenario 2 / Scenario 1

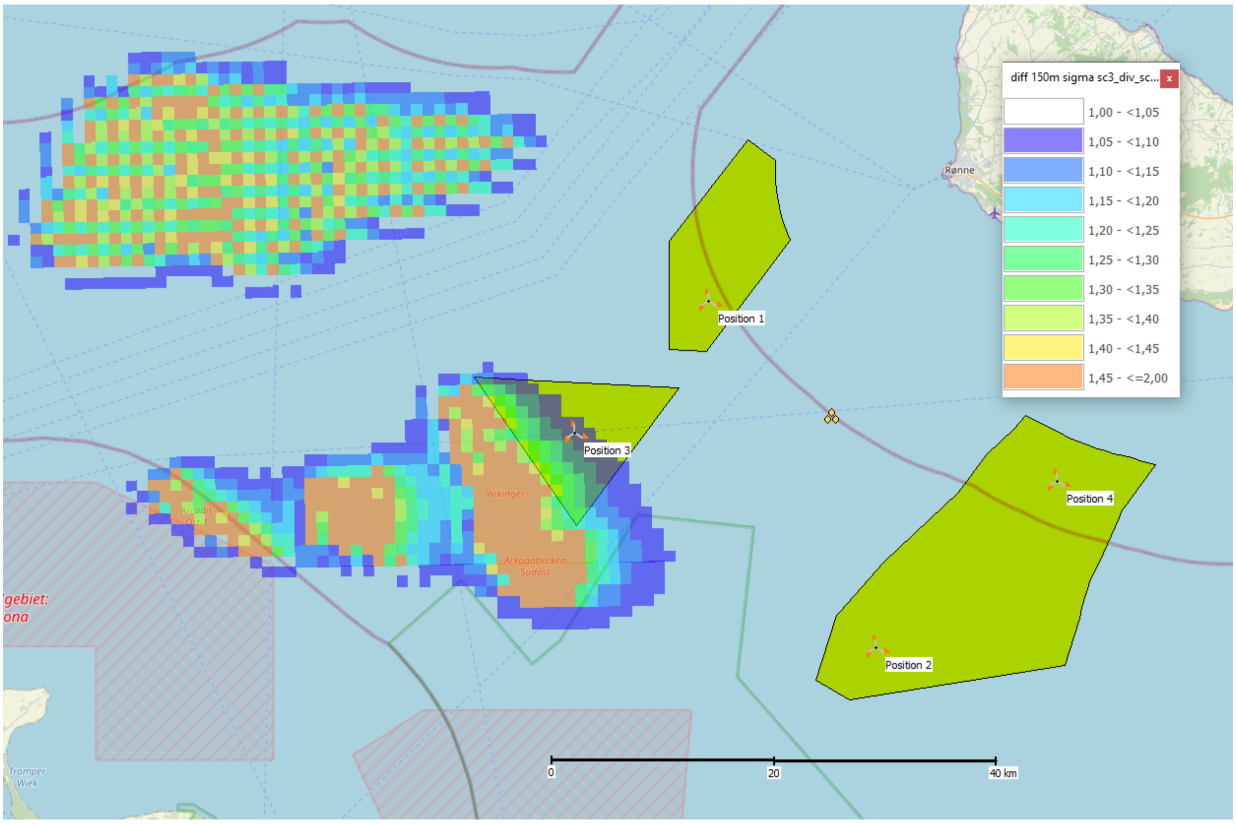

Figure 15. Ratio of average sigma, Scenario 3 / Scenario 1

5.3 Turbulence results

The turbulence model presented in [1] remains valid for Position 1, 2 and 4.

For Position 3, the turbulence model is valid for all direction sectors except for the intervals presented in Table 21. Within these intervals, we suggest to replace the turbulence intensity values according to the graphs in Figure 16 to Figure 18 for scenario 2 and as in Figure 19 to Figure 21 in scenario 3 and 4.

The turbulence values are tabulated in Appendix A.

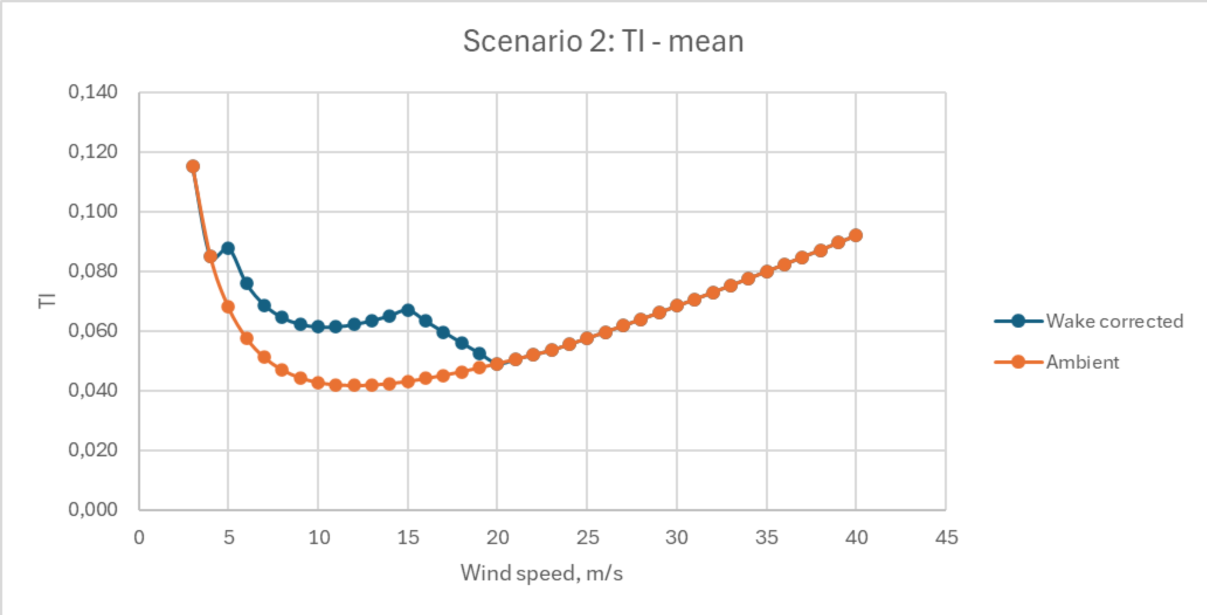

Figure 16. Mean turbulence intensity model, the reported model (ambient) and the corrected model. Position 3, scenario 2.

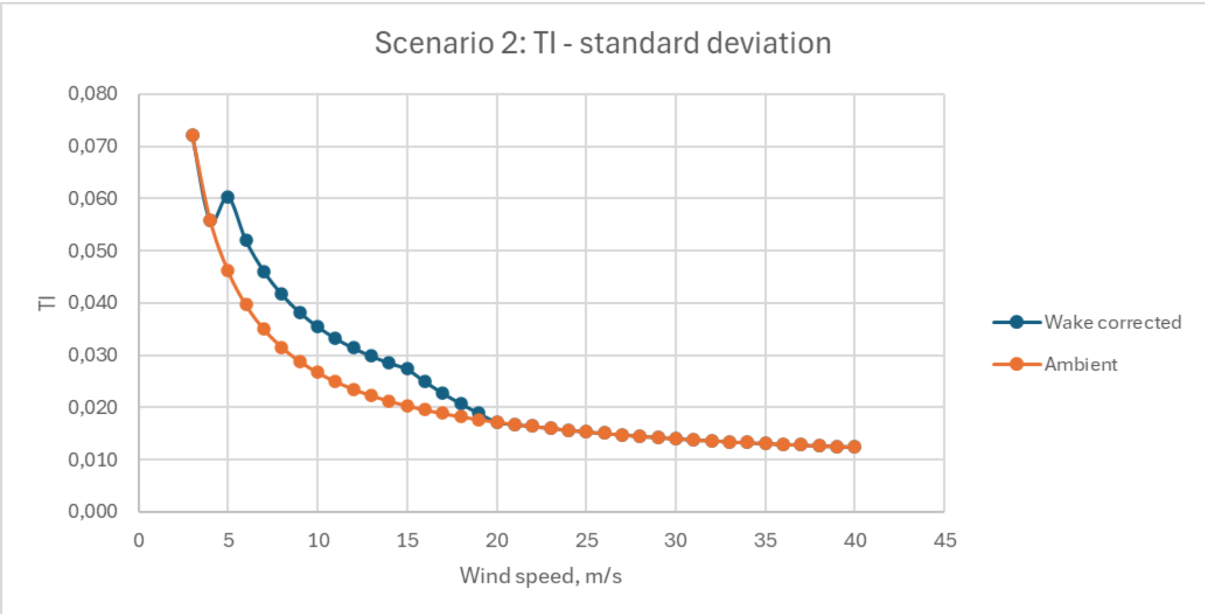

Figure 17. Standard deviation of turbulence intensity model, the reported model (ambient) and the corrected model. Position 3, scenario 2.

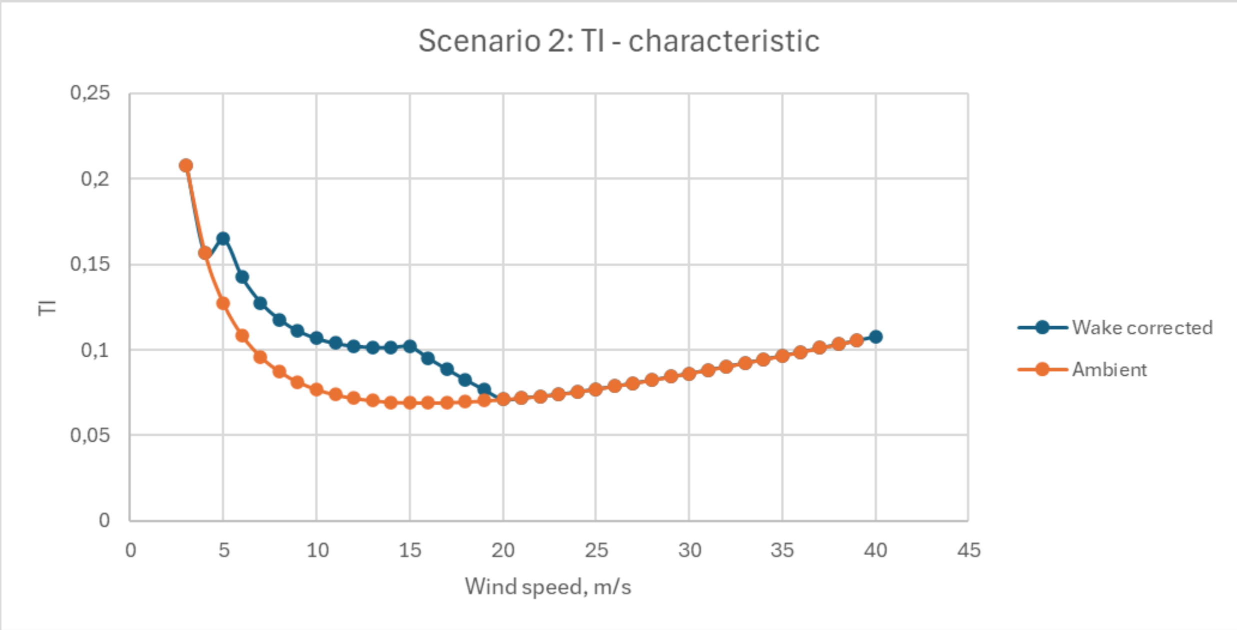

Figure 18. Characteristic turbulence intensity model, the reported model (ambient) and the corrected model. Position 3, scenario 2.

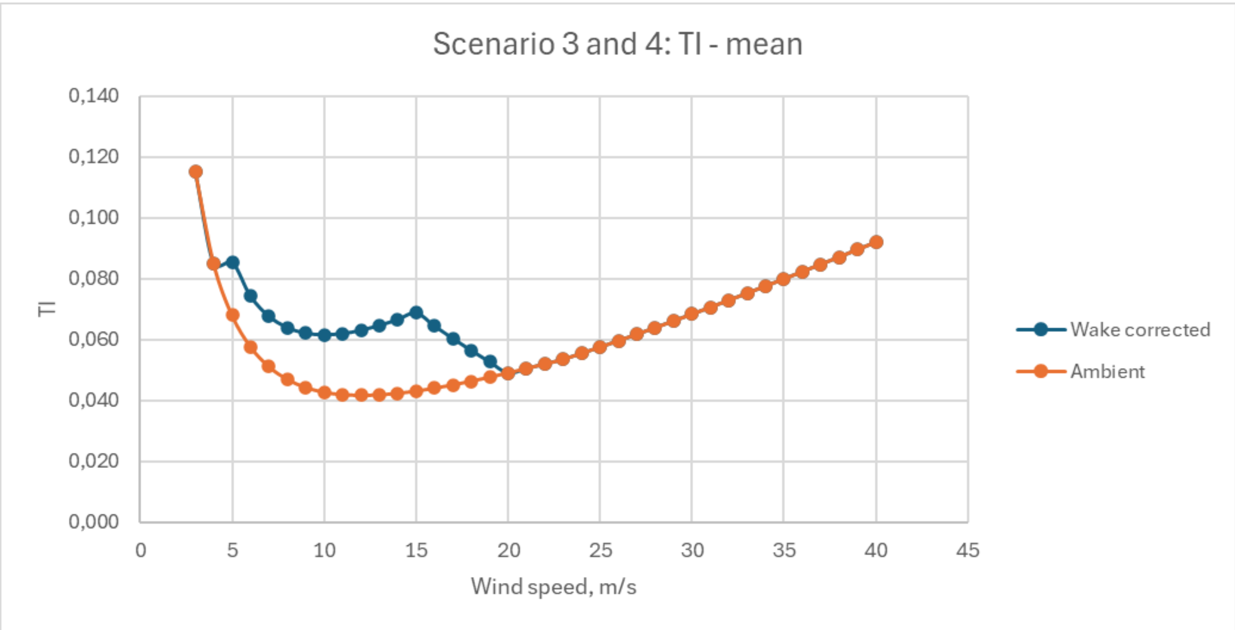

Figure 19, Mean turbulence intensity model, the reported model (ambient) and the corrected model. Position 3, scenario 3 and 4.

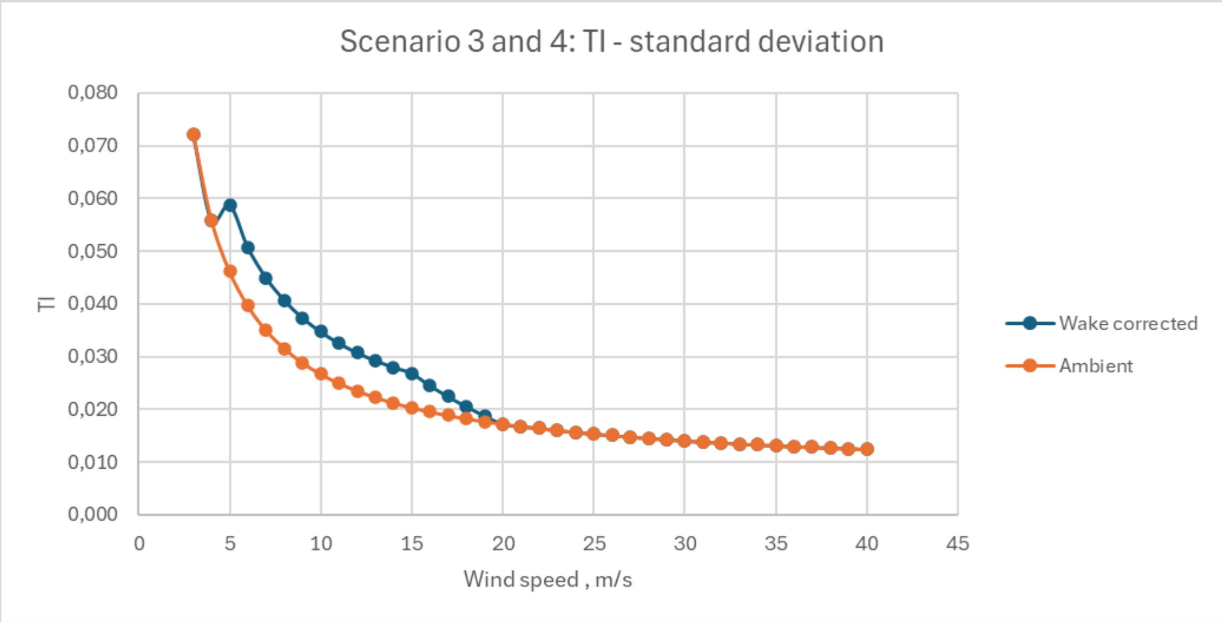

Figure 20. Standard deviation of turbulence intensity model, the reported model (ambient) and the corrected model. Position 3, scenario 4 and 4.

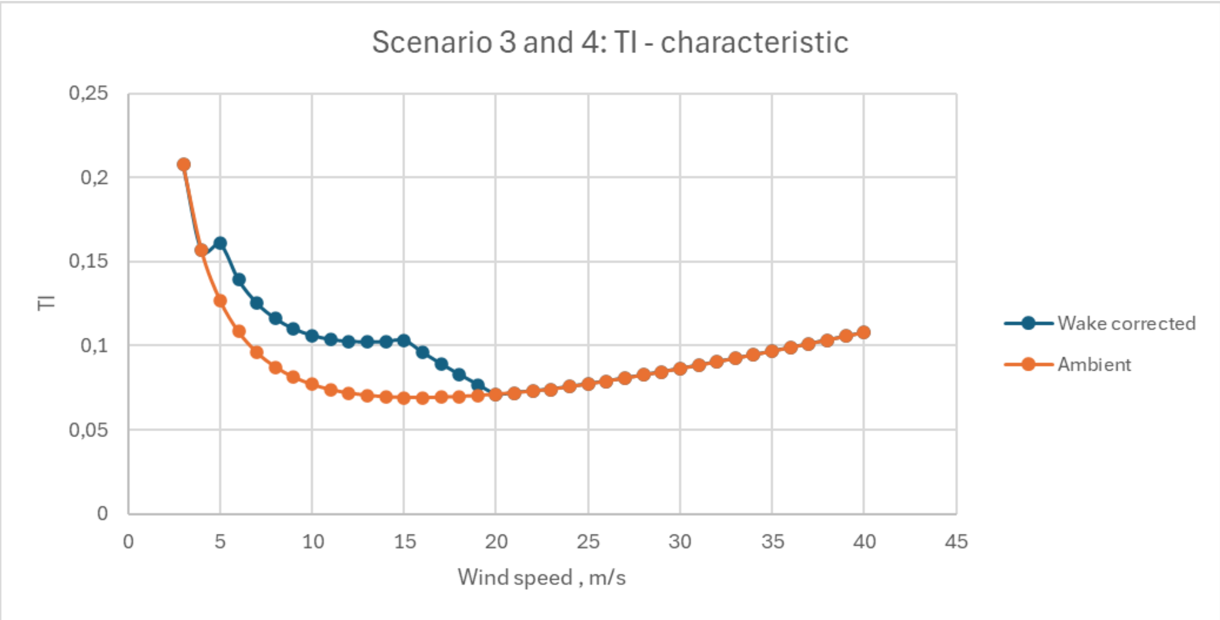

Figure 21. Characteristic turbulence intensity model, the reported model (ambient) and the corrected model. Position 3, scenario 3 and 4.

The key turbulence intensity values for 15 m/s for the alternative turbulence model are presented in Table 22

Table 22. Turbulence intensity values for the alternative model at 15 m/s. The alternative model is suggested for Position 3 in the interval 165˚-225˚ (sector 7-8) for scenario 2 and 165˚-255˚(sector 7-9) for scenario 3 and 4.

TURBULENCE MODEL PARAMETERS AT THE SITE	TURBULENCE MEAN VALUE	STANDARD DEVIATION OF TURBULENCE	TURBULENCE CHARACTERISTIC VALUE
Scenario 2	6.7%	2.7%	10.1%
Scenario 3	6.9%	2.7%	10.3%
Scenario 4	6.9%	2.7%	10.3%

6 Alternative site wind conditions parameters

Based on the WRF wake study presented here, EMD suggests alternative site wind conditions parameters as listed below. Parameters not in bold are not considered in this study and are therefore identical to those presented in the site wind conditions assessment.

The alternative turbulence model is presented in brackets and is only suggested for the interval presented in Table 21.

Table 23. Summary tables of Site Wind Condition parameters at the four selected positions on the Baltic Sea Energy Island OWF zone. All values refer to 150 m height above sea level (ASL) and are based on 1 (Position 1 and 3) or 2 years (Position 2 and 4) of onsite measurements adjusted for the impact of wind turbines. ***Numbers in bold include WRF modelled wake effects, not-bold numbers are from the site wind conditions assessment****. The turbulence parameters in bracket is the alternative turbulence model, suggested for a limited wind direction interval (scenario 2: sector 7-8, scenario 3: sector 7-9)*

SCENARIO 2	POSITION 1	POSITION 2	POSITION 3	POSITION 4
Mean wind speed	9.92 m/s	9.94 m/s	**9.68 m/s**	**9.98 m/s**
Weibull distribution, A parameter (scale)	11.20 m/s	11.22 m/s	**10.93 m/s**	**11.27 m/s**
Weibull distribution, k parameter (shape)	2.18	2.20	**2.16**	**2.19**
Turbulence intensity mean value (TI_μ) at a 10-min average wind speed of 15m/s*	4.3%	4.3%	4.3% **(6.7%)**	4.3%
Turbulence intensity standard deviation (TI_σ) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0% **(2.7%)**	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	6.9%	6.9%	6.9% **(10.1%)**	6.9%

SCENARIO 3	POSITION 1	POSITION 2	POSITION 3	POSITION 4
Mean wind speed	**9.65 m/s**	**9.88 m/s**	**9.15 m/s**	**9.90 m/s**
Weibull distribution, A parameter (scale)	**10.89 m/s**	**11.16 m/s**	**10.33 m/s**	**11.18 m/s**
Weibull distribution, k parameter (shape)	**2.17**	**2.19**	**2.11**	**2.19**
Turbulence intensity mean value (TI_{μ}) at a 10-min average wind speed of 15m/s*	4.3%	4.3%	4.3% **(6.9%)**	4.3%
Turbulence intensity standard deviation (TI_{σ}) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0% **(2.7%)**	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	6.9%	6.9%	6.9% **(10.3%)**	6.9%

SCENARIO 4	POSITION 1	POSITION 2	POSITION 3	POSITION 4
Mean wind speed	**9.57 m/s**	**9.80 m/s**	**9.01 m/s**	**9.80 m/s**
Weibull distribution, A parameter (scale)	**10.81 m/s**	**11.06 m/s**	**10.17 m/s**	**11.07 m/s**
Weibull distribution, k parameter (shape)	**2.16**	**2.17**	**1.83**	**2.17**
Turbulence intensity mean value (TI_{μ}) at a 10-min average wind speed of 15m/s*	4.3%	4.3%	4.3% **(6.9%)**	4.3%
Turbulence intensity standard deviation (TI_{σ}) at a 10-min average wind speed of 15m/s*	2.0%	2.0%	2.0% **(2.7%)**	2.0%
Turbulence intensity 90% quantile at a 10-min average wind speed of 15m/s*	6.9%	6.9%	6.9% **(10.3%)**	6.9%

7 Deliverables

EMD has submitted datasets in support of this study. These are as far as it is possible provided in accessible formats.

7.1 Adjusted datasets for Position 1-4

The long-term corrected and windfarm wakes adjusted time series at Position 1. 2. 3 and 4 are included in the data package. All positions include only the 150 m height. Data available for Scenario 2. 3 and 4.

- Position 1 scenario 2.txt
- Position 1 scenario 3.txt
- Position 1 scenario 4.txt
- Position 2 scenario 2.txt
- Position 2 scenario 3.txt
- Position 2 scenario 4.txt
- Position 3 scenario 2.txt
- Position 3 scenario 3.txt
- Position 3 scenario 4.txt
- Position 4 scenario 2.txt
- Position 4 scenario 3.txt
- Position 4 scenario 4.txt

Parameters included are wind speed and wind direction. Data format follows the standard format. The text file can be imported directly into windPRO. but as an open format. it is generally accessible.

7.2 Tiff maps

The WRF maps are made available as ratio maps, giving the ratios of omnidirectional mean wind speed and omnidirectional sigma values. The maps are in Tiff format, using the coordinate system UTM ETRS89, zone 33.

The following maps are provided:

diff 150m ws sc2_div_sc1.tiff

diff 150m ws sc3_div_sc1.tiff

diff 150m ws sc4_div_sc1.tiff

diff 150m ws sc3_div_sc2.tiff

diff 150m ws sc4_div_sc2.tiff

diff 150m sigma sc2_div_sc1.tiff

diff 150m sigma sc3_div_sc1.tiff

Where,

150m denotes height above mean sea level

Ws denotes wind speed

Sc denotes scenario.

7.3 EMD-WRF time series

The EMD-WRF datasets calculated for the typical year 2004 are submitted to Energinet.

The dataset is split into 4 folders, one for each scenario. Each folder contains a number of zip files that contain the raw time series data. A CSV file will be provided that contains mapping from latitude/longitude to the appropriate ZIP file.

8 References

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Appendix A. Alternative Normal Turbulence Model (150 m), for use at position 3, scenario 2 sector 7-8.

Wind speed [m/s]	Turbulence intensity mean value (TI_{μ}) [%]	Turbulence intensity standard deviation (TI_{σ}) [%]	Turbulence intensity 90% quantile [%]
3	11.5	7.2	20.8
4	8.5	5.6	15.6
5	8.8	6.0	16.5
6	7.6	5.2	14.2
7	6.9	4.6	12.8
8	6.4	4.2	11.8
9	6.2	3.8	11.1
10	6.1	3.5	10.7
11	6.1	3.3	10.4
12	6.2	3.1	10.2
13	6.3	3.0	10.1
14	6.5	2.8	10.1
15	6.7	2.7	10.2
16	6.3	2.5	9.5
17	6.0	2.3	8.9
18	5.6	2.1	8.2
19	5.2	1.9	7.7
20	4.9	1.7	7.1
21	5.0	1.7	7.2
22	5.2	1.6	7.3
23	5.3	1.6	7.4
24	5.5	1.6	7.6
25	5.7	1.5	7.7

Wind speed [m/s]	TURBULENCE MEAN VALUE (σ_μ) [M/S]	TURBULENCE STANDARD DEVIATION (σ_σ) [M/S]	Turbulence 90% QUANTILE [m/s]
3	0.35	0.22	0.62
4	0.34	0.22	0.63
5	0.44	0.30	0.83
6	0.46	0.31	0.85
7	0.48	0.32	0.89
8	0.52	0.33	0.94
9	0.56	0.34	1.00
10	0.61	0.35	1.07
11	0.67	0.37	1.14
12	0.74	0.38	1.23
13	0.82	0.39	1.32
14	0.91	0.40	1.42
15	1.00	0.41	1.53
16	1.01	0.40	1.52
17	1.01	0.39	1.51
18	1.01	0.37	1.48
19	1.00	0.36	1.46
20	0.98	0.34	1.42
21	1.06	0.35	1.51
22	1.14	0.36	1.60
23	1.23	0.37	1.70
24	1.33	0.38	1.81
25	1.44	0.38	1.93

Appendix B. Alternative Normal Turbulence Model (150 m), for use at position 3, scenario 3 and 4, sector 7-9.

Wind speed [m/s]	Turbulence intensity mean value (TI_{μ}) [%]	Turbulence intensity standard deviation (TI_{σ}) [%]	Turbulence intensity 90% quantile [%]
3	11.5	7.2	20.8
4	8.5	5.6	15.6
5	8.5	5.9	16.1
6	7.4	5.1	13.9
7	6.8	4.5	12.5
8	6.4	4.1	11.6
9	6.2	3.7	11.0
10	6.2	3.5	10.6
11	6.2	3.3	10.4
12	6.3	3.1	10.2
13	6.5	2.9	10.2
14	6.6	2.8	10.2
15	6.9	2.7	10.3
16	6.4	2.5	9.6
17	6.0	2.2	8.9
18	5.6	2.1	8.3
19	5.3	1.9	7.7
20	4.9	1.7	7.1
21	5.0	1.7	7.2
22	5.2	1.6	7.3
23	5.3	1.6	7.4
24	5.5	1.6	7.6
25	5.7	1.5	7.7

Wind speed [m/s]	Turbulence mean value (σ_μ) [m/s]	Turbulence standard deviation (σ_σ) [m/s]	Turbulence 90% quantile [m/s]
3	0.35	0.22	0.62
4	0.34	0.22	0.63
5	0.43	0.29	0.80
6	0.45	0.30	0.83
7	0.47	0.31	0.88
8	0.51	0.33	0.93
9	0.56	0.34	0.99
10	0.62	0.35	1.06
11	0.68	0.36	1.14
12	0.76	0.37	1.23
13	0.84	0.38	1.33
14	0.93	0.39	1.43
15	1.03	0.40	1.55
16	1.03	0.39	1.53
17	1.03	0.38	1.51
18	1.01	0.37	1.49
19	1.00	0.36	1.46
20	0.98	0.34	1.42
21	1.06	0.35	1.51
22	1.14	0.36	1.60
23	1.23	0.37	1.70
24	1.33	0.38	1.81
25	1.44	0.38	1.93