European Commission

Clean energy for EU islands: Long-term yield assessment Fejo Wind Farm, Fejo Island, Denmark

Clean energy
for EU islands

Long-term yield assessment
Fejo Wind Farm, Fejo Island, Denmark

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Table of Contents

GLOSSARY

AEP	Annual Energy Production
AGL / ASL	Above Ground Level / Above Sea Level
BOP	BOP (Balance of Plant) corresponds to civil and electrical infrastructures inside the wind farm (inter-array cables, junction boxes, foundations, etc.).
CORINE LAND COVER	The Corine Land Cover database is an inventory of land cover in 44 classes. It was initiated in 1985 by the European Union and has been taken over by the EEA. 3E associates roughness information to each class in order to create roughness maps that are used in the wind flow models.
DISPLACEMENT HEIGHT	Large areas of tall obstacles affect the wind shear, lifting the zero velocity theoretical height by a value called the displacement height.
DSM / DEM	As opposed to DTM (Digital Terrain Model), DSM / DEM (Digital Surface Model or Digital Elevation Model) includes objects on the ground surface like forests and buildings.
ERA-5	ERA-5 is an hourly reanalysis dataset produced by the European Centre for Medium-Range Weather Forecast (ECMWF) cover a period from 1979 to the present. It extends to the whole of earth on a grid of 30km, resolving the atmosphere using 137 levels from the surface up to a height of 80km.
EU-DEM	The Digital Elevation Model over Europe from the GMES RDA project (EU-DEM) is a Digital Surface Model (DSM) representing the first surface as illuminated by the sensors. The EU-DEM dataset is a realisation of the Copernicus programme, managed by the European Commission, DG Enterprise and Industry.
HH	Hub height
MERRA-2	MERRA-2, the Modern Era Retrospective Analysis for Research and Applications is a reanalysis dataset from NASA. It covers the period from 1980 to present with a resolution of 1/2° x 0.625° (latitude x longitude).
NORMAL DISTRIBUTION	In probability theory, the normal (or Gaussian) distribution is a bell-shaped continuous probability distribution function with two parameters: the mean and the standard deviation. Normal distributions are extremely important in statistics and are often used in the natural sciences for real-valued random variables whose distributions are not known. One reason for their popularity is the central limit theorem (CLT), which states that, under mild conditions, the mean of a large number of random variables independently drawn from the same distribution is distributed approximately normally, irrespective of the form of the original distribution.
PROBABILITY OF EXCEEDANCE	In probability theory and statistics, the probability of exceedance is a number (in the range 0 to 100%) that represents the probability that a random variable falls above (or exceeds) a certain value. It is calculated as one minus the cumulative distribution function (CDF),

	which describes the probability that a variable will be found at a value less than or equal to X.
RD	Rotor diameter
REANALYSIS	Reanalysis data are the results of a meteorological data assimilation process that aims to assimilate historical observational data spanning an extended period, using a single consistent assimilation (or “analysis”) scheme throughout this period.
RIX	The ruggedness index (RIX) at a specific location is the percentage of the ground surface that has a slope above a given threshold (e.g. 40%) within a certain distance.
RP	Rated power
TURBINE INTERACTION LOSSES	Combined production losses due to interaction effects (wake and blockage) between wind turbines within a wind farm.
WAKE LOSSES	The wake losses are production losses due to the mutual interaction of wind turbines, caused by the wind energy deficit downstream of the wind turbine rotors.
WASP	WAsP (Wind Atlas Analysis and Application Program) is a software package that simulates wind flows for predicting wind climates, wind resources, and power productions from wind turbines and wind farms. WAsP is developed and distributed by DTU Wind Energy, Denmark. It has become the wind power industry-standard PC-software for wind resource assessment.
WEIBULL DISTRIBUTION	In probability theory and statistics, the Weibull distribution is a continuous probability distribution function with two parameters: k (shape) and A (scale). It is widely used in the wind power community as an approximation of the frequency distribution of wind speeds from a time series.
WIND FARM BLOCKAGE LOSS	Difference in production due to the accumulated induction effect of the wind farm between a turbine when operating in isolation and when operating in an array.
WIND INDEX	The wind index of a period quantifies the windiness of this period compared to a long-term reference period. It is usually done in terms of wind turbine power output. The long-term period is given an index of 100. Hence, a period with an index of 105 is 5% windier than the long-term. In this case, the long-term correction factor is 0.95.
WIND REGIME	In the WAsP methodology, the wind rose is divided into 12 sectors et the wind speed distribution in each sector is approximated by a Weibull distribution defined by 2 parameters A & k. A wind regime is defined by these parameters A & k, as well as the weight of each wind sector.
WIND SHEAR	The wind shear is a measure of how the wind speed decreases in the lower atmosphere close to the ground. This phenomenon is due to the drag forces exerted by the ground and its roughness on the air flow. It shapes the wind speed and turbulence profiles, the former of which is often described with a logarithmic or exponential law.
WINDPRO	WindPRO is a software package for designing and planning wind farm projects. It uses WAsP to simulate wind flows. It is developed and distributed by the Danish energy consultant EMD International A/S. It is trusted by many investment banks to create wind energy assessments used to determine financing for proposed wind farms.

SUMMARY

This report presents results of the preconstruction long-term energy yield assessment of the Fejo wind farm, located on Fejo island, in Denmark. 6 wind farm configurations were considered, for a total installed capacity of 2 to 3 MW:

- Layout 0 (i): 1 Vestas V80 2 MW wind turbine with 80 m rotor diameter and 80 m hub height in Osterby,
- Layout 0 (ii): 1 Vestas V80 2 MW wind turbine with 80 m rotor diameter and 60 m hub height in Osterby,
- Layout 0 (iii): 1 Enercon E82 EP3 E4 3 MW wind turbine with 82 m rotor diameter and 78 m hub height in Osterby,
- Layout 0 (iv): 1 Enercon E82 EP3 E4 3 MW wind turbine with 82 m rotor diameter and 69 m hub height in Osterby,
- Layout 0 (v): Leitwind LWT80 1.8 MW turbine with 80.3 m rotor diameter and 65 m hub height in Osterby,
- Layout 1: 3 Vestas V52 0.85 MW wind turbines with 52 m rotor diameter and 55 m hub height in a first layout scenario, in Osterby and Vesterby
- Layout 2: 3 Vestas V52 0.85 MW wind turbines with 52 m rotor diameter and 55 m hub height in a second layout scenario, in Osterby
- Layout 3: 1 Vestas V80 2 MW wind turbine with 80 m rotor diameter and 60 m hub height, in Skalo
- Layout 4: 3 Vestas V52 0.85 MW wind turbines with 52 m rotor diameter and 55 m hub height, in Skalo and Osterby.

This preliminary stage study is based on wind statistics points generated from the closest ERA5 point (ERA5 55.0°N 11.5°E) around the site at 100 m of height above ground level. The terrain at site was modelled (elevation, roughness and obstacles to the wind flow) and the wind flow model WAsP was used to extrapolate the wind regime to the location and hub height of each wind turbine. Concerning the wind regime on site, as a representative example, the expected Weibull mean wind speed at the location of wind turbine WT1 (cfr. Figure 7, pink legend) at 80 m AGL is of 8.2 m/s, with prevailing wind directions West (W) and West-South-West (WSW).

The wind regime at the location and hub height of each wind turbine was then combined with the air density-adjusted power curves of each considered wind turbine type, to assess its gross energy production. Energy production losses were assessed and deducted from the gross energy production of each wind turbine, resulting in its expected net annual energy production ('AEP'). Losses associated with grid curtailment were included, related to the limited capacity of the connection cable between Fejo and the mainland. This curtailment is the only one that applies in this report.

Energy production losses taken into account in this study range between 6.3 % and 7.7 % depending on the wind farm configuration and break down as follows:

Configuration		1x V80, 2 MW @ 80 m	1x V80, 2 MW @ 60 m	1x E82 EP3 E4, 3 MW @ 78 m	1x E82 EP3 E4, 3 MW @ 69 m	1x LWT80, 1.8 MW @ 65 m
Scenario		Layout 0 (i)	Layout 0 (ii)	Layout 0 (iii)	Layout 0 (iv)	Layout 0 (v)
Turbine interaction losses	[%]	0.0	0.0	0.0	0.0	0.0
Unavailability losses	[%]	3.5	3.5	3.5	3.5	3.5
Turbine	[%]	3.0	3.0	3.0	3.0	3.0
BOP	[%]	0.2	0.2	0.2	0.2	0.2
Grid	[%]	0.3	0.3	0.3	0.3	0.3
Performance losses	**[%]**	0.7	0.7	0.7	0.7	0.7
Non-standard wind flow conditions	[%]	0.5	0.5	0.5	0.5	0.5
Turbine control limitation	[%]	0.2	0.2	0.2	0.2	0.2
Electrical losses	**[%]**	1.5	1.5	1.5	1.5	1.5
Environmental losses	**[%]**	0.7	0.7	0.7	0.7	0.7
Performance degradation not due to icing	[%]	0.3	0.3	0.3	0.3	0.3
Performance degradation due to icing	[%]	0.2	0.2	0.2	0.2	0.2
Shutdown due to icing	[%]	0.2	0.2	0.2	0.2	0.2
Curtailment losses	**[%]**	0.0	0.0	0.0	0.0	0.0
Total losses	**[%]**	**6.3**	**6.3**	**6.3**	**6.3**	**6.3**

Configuration		V52, 0.85 MW @ 55 m	V52, 0.85 MW @ 55 m	V80, 2 MW @ 60 m	V52, 0.85 MW @ 55 m
Scenario		Layout 1	Layout 2	Layout 3	Layout 4
Turbine interaction losses	[%]	0.1	1.5	0.0	0.9
Unavailability losses	[%]	3.5	3.5	3.5	3.5
Turbine	[%]	3.0	3.0	3.0	3.0
BOP	[%]	0.2	0.2	0.2	0.2
Grid	[%]	0.3	0.3	0.3	0.3
Performance losses	**[%]**	0.7	0.7	0.7	0.7
Non-standard wind flow conditions	[%]	0.5	0.5	0.5	0.5
Turbine control limitation	[%]	0.2	0.2	0.2	0.2
Electrical losses	**[%]**	1.5	1.5	1.5	1.5
Environmental losses	**[%]**	0.7	0.7	0.7	0.7
Performance degradation not due to icing	[%]	0.3	0.3	0.3	0.3
Performance degradation due to icing	[%]	0.2	0.2	0.2	0.2
Shutdown due to icing	[%]	0.2	0.2	0.2	0.2
Curtailment losses	**[%]**	0.0	0.0	0.0	0.0
Total losses	**[%]**	**6.3**	**7.7**	**6.3**	**7.1**

The resulting production from the different configurations is summarised in the following:

Configuration		1x V80, 2 MW @ 80 m	1x V80, 2 MW @ 60 m	1x E82 EP3 E4, 3 MW @ 78 m	1x E82 EP3 E4, 3 MW @ 69 m	1x LWT80, 1.8 MW @ 65 m
Scenario		Layout 0 (i)	Layout 0 (ii)	Layout 0 (iii)	Layout 0 (iv)	Layout 0 (v)
Gross energy production	[MWh/y]	7,574	6,702	9,182	8,700	6,618
Total energy production losses	[%]	6.3	6.3	6.3	6.3	6.3

Net energy production (AEP)	**[MWh/y]**	7,100	6,283	8,608	8,156	6,204
Net full load equivalent hours	[h/y]	3,550	3,142	2,869	2,719	3,447

Configuration		**3x V52, 0.85 MW @ 55 m**	**3x V52, 0.85 MW @ 55 m**	**3x V80, 2 MW @ 60 m**	**3x V52, 0.85 MW @ 55 m**
Scenario		Layout 1	Layout 2	Layout 3	Layout 4
Gross energy production	[MWh/y]	8,256	8,331	7,430	8,617
Total energy production losses	[%]	6.3	7.7	6.3	7.1
Net energy production (AEP)	**[MWh/y]**	7,732	7,692	6,966	8,003
Net full load equivalent hours	[h/y]	3,032	3,016	3,483	3,138

The Clean energy for EU islands secretariat would like to remind the reader that the results presented in this report are only valid if the following aspects considered in the study are consistent with those of the turbine supply agreement:

- Power curves,
- Noise curtailment strategy,
- Shadow flicker curtailment strategy,
- Wind Sector Management,
- Grid curtailment strategy.

The Clean energy for EU islands secretariat is an initiative by the European Commission. This publication does not involve the European Commission in liability of any kind.

1. Introduction

1.1. Objectives

Within the technical assistance of the CE4EUI secretariat to the island of Fejo, it was agreed to assess the long-term energy production of the Fejo wind farm project, as well as energy productions exceeded with various probabilities. Results of the study are suited for a financial analysis of the project.

1.2. Methodology

This study is carried out according to the best industry practices [1][2] and managed according to the ISO 9001:2008 standard, under which 3E has been certified since 2010.

1.3. Outline of the report

- Section 2 details the site and project, including the site location and environment, the available wind measurements, and the wind farm configurations to be studied,
- Section 3 details the processing of wind data into a representative wind regime meant for energy production calculations,
- Section 4 details wind flow modelling,
- Section 5 details energy production calculations,
- Section 6 details the calculation of energy productions exceeded with various probabilities,
- Section 7 summarizes the findings of the study and provides recommendations.

2. Site and Project Description

2.1. Site Description

2.1.1. Landscape

The site is located on the island of Fejo, as indicated in Figure 1. The island is mainly occupied by cultivated fields, with only two agglomerations of small size. The terrain is rather flat as illustrated in ANNEX A. There are a few roads that ensure that most of the dwellings on site can be accessed.

Two existing wind turbines are located on the island:

- 1 wind turbine, located at the North of Osterby and consisting in 1 Wind World W2700 150 kW wind turbine with 30 m hub height,
- 1 wind turbine, located on Skalo island and consisting in 1 Vestas V15 55 kW wind turbine with 18 m hub height.

Figure 1: Site location (Source: Google Earth 2022)

2.1.2. Regulations

As communicated by the Client, there exists regulation applicable to wind turbine construction on this island. The 4 main points are listed here below:

- The island is partly part of a Natura 2000 designated area. Natura 2000 comprises a collection of nature conservation sites within the European Union. These sites are designated as Special Areas of Conservation and Special Protection Areas under the Habitats Directive and the Birds Directive, respectively. As a result, no wind turbine can be placed in such an area. In particular, the NW zone of the island, Skalo, is part of this zone, resulting in the fact that the currently existing wind turbine cannot be replaced at the same location. This forbidden zone is highlighted in orange on Figure 2.
- It is forbidden to place any turbines closer than 300 meters from the beach protection areas. The allowed zone is highlighted in pink on Figure 3. As a result of this regulation, it appears that none of the two existing turbine location can be used to place the new turbine.
- It is forbidden to place a turbine closer than 4 times the total height of the turbine to dwellings. This forbidden zone is highlighted in pink on Figure 4 and Figure 5.
- The island can only export a maximum of 3 MW to the grid connection point.

Also, noise regulations apply, which requires at least the chosen turbine to have several noise mode available, in case further acoustic impact studies require the wind turbine to be curtailed.

As a result of this analysis, it appears that for turbines with total height larger than 80 m, only a single location is possible on the island. This corresponds to layout 0, in Figure 7. For the smaller turbines, two layouts are possible: layouts 1 and 2 shown in Figure 8 and Figure 9.

Figure 2: Natura 2000 forbidden zone

Figure 3: 300 m beach protection area

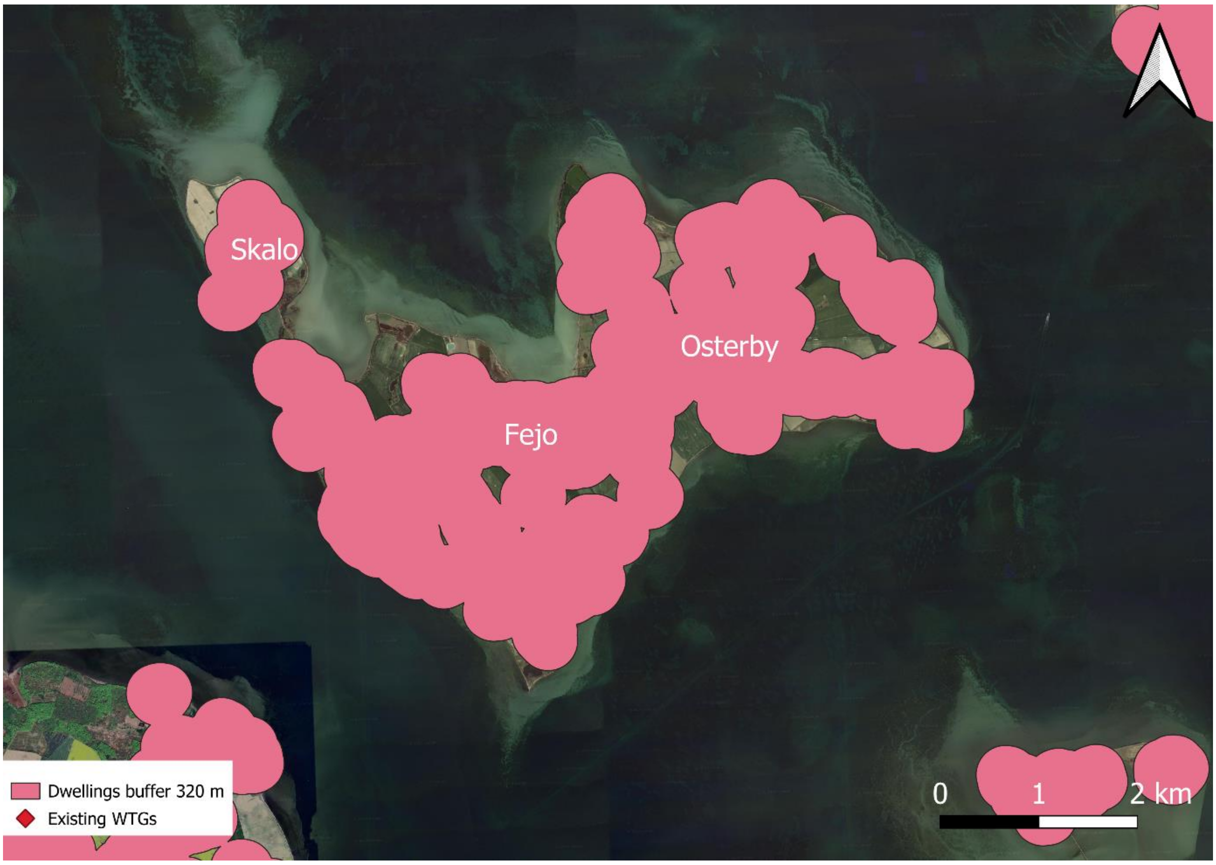

Figure 4: Forbidden zone for 100 m total height turbines

Figure 5: Forbidden zone for 120 m total height turbines

Figure 6: allowed area for the different proposed layouts

2.1.3. Energy demand

Based on information provided by the Client, the energy demand can be summarized as shown in Table 1. These computations have been based on a stable island population of 500 people. The estimate provided is largely inaccurate and will require more in-depth thoughts in further project development stages.

Table 1: Final energy demand

Category		**Consumption**
Electricity	[GWh/y]	3.2
Transport	[GWh/y]	1.4
Heating	[GWh/y]	1.3
Total	**[GWh/y]**	**5.9**

2.2. Available wind measurements

No wind measurement campaign has been carried out on site for the present project. Hence, this study uses the wind statistics generated from the closest ERA5 point. This results in higher uncertainties values regarding the results, but trends can be considered as correct.

2.3. Wind farm configurations

In this report, a configuration refers to the combination of a wind farm layout and a wind turbine type (turbine model + hub height). 9 configurations are considered, comprising 1 to 3 turbines for a total installed capacity of 2 to 3 MW. The configurations to be studied have been suggested by the Client as well as chosen by 3E and are detailed in Table 1. The various wind farm layouts are illustrated Figure 7 to Figure 9, whereas wind turbines coordinates are listed in ANNEX B.

Table 2: Wind farm configurations (1/2)

Configuration		**V80, 2 MW @ 80 m**	**V80, 2 MW @ 60 m**	**E82 EP3 E4, 3 MW @ 78 m**	**E82 EP3 E4, 3 MW @ 69 m**	**LWT80, 1.8 MW @ 65 m**
Scenario		**Layout 0 (i)**	**Layout 0 (ii)**	**Layout 0 (iii)**	**Layout 0 (iv)**	**Layout 0 (v)**
Wind turbine manufacturer	[-]	Vestas	Vestas	Enercon	Enercon	Leitwind
Wind turbine type	[-]	V80	V80	E82 EP3 E4	E82 EP3 E4	LWT80
Number of wind turbines	[-]	1	1	1	1	1
Rated power per turbine	[MW]	2	2	3	3	1.8
Total rated power	[MW]	2.0	2.0	3.0	3.0	1.8
Rotor diameter	[m]	80	80	82	82	80.3
Hub height	[m]	80	60	78	69	65

Table 3: Wind farm configurations (2/2)

Configuration		V52, 0.85 MW @ 55 m	V52, 0.85 MW @ 55 m	V80, 2 MW @ 60 m	V52, 0.85 MW @ 55 m
		Layout 1	Layout 2	Layout 3	Layout 4
Wind turbine manufacturer	[-]	Vestas	Vestas	Vestas	Vestas
Wind turbine type	[-]	V52	V52	V80	V52
Number of wind turbines	[-]	3	3	1	3
Rated power per turbine	[MW]	0.85	0.85	2	0.85
Total rated power	[MW]	2.6	2.6	2.0	2.6
Rotor diameter	[m]	52	52	80	52
Hub height	[m]	55	55	60	55

Figure 7: Aerial picture of the site with wind turbines (layout 0) (Source: Google Earth, 2022)

Figure 8 : Aerial picture of the site with wind turbines (layout 1) (Source: Google Earth, 2022)

Figure 9 : Aerial picture of the site with wind turbines (layout 2) (Source: Google Earth, 2022)

Figure 10 : Aerial picture of the site with wind turbines (layout 3) (Source: Google Earth, 2022)

Figure 11 : Aerial picture of the site with wind turbines (layout 4) (Source: Google Earth, 2022)

3. Wind Data Processing

3.1. Preliminary remarks

For each project, 3E selects the most appropriate wind resource dataset, depending on the site location, the existence of wind statistics nearby, and the ability of these statistics to predict electrical production and measured data in the surroundings.

For this study, 3E has used the closest ERA5 point to the site. This dataset is the fifth generation ECMWF reanalysis for the global climate and weather. It combines model data with observations across the world based on the principle of data assimilation, to deliver hourly estimates of several atmospheric quantities [4]. This dataset spans the 8 last decades but for the purposes of this analysis, only the last 20 years have been selected.

3.2. Selected wind statistics

For this project, the closest ERA5 point to the site is the ERA5 55.0°N 11.5°E. Its location is shown in Figure 12.

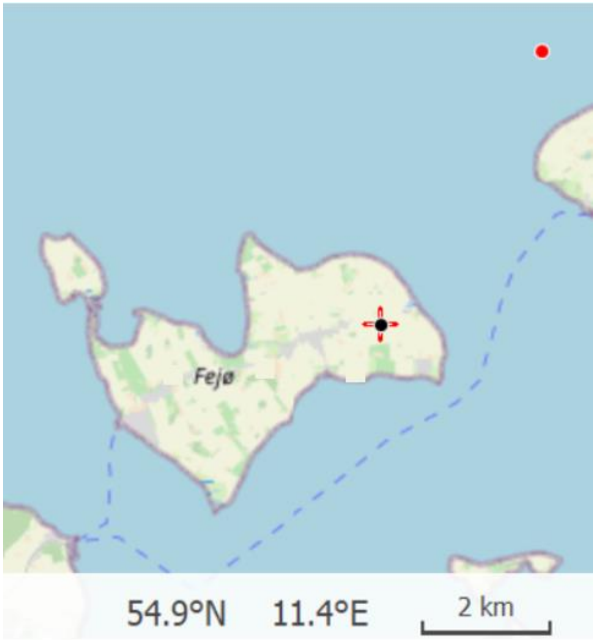

Figure 12 : Selected wind statistics

4. Wind Flow Modelling

4.1. Terrain model

Terrain features influence the wind flow and thus play a significant role in the spatial extrapolation of the wind regime. The software package WindPRO and the WAsP wind flow model are used in the present study. WAsP requires a terrain model describing elevation, roughness and other relevant obstacles to the wind flow that are not modelled as roughness (cf. ANNEX C).

The terrain model used in this study represents the current conditions, which are assumed to remain the same over the wind farm lifetime.

4.1.1. Elevation

The wind regime can be highly influenced by elevation differences across the site. For this study, terrain elevation is modelled within a radius of 15 km (in line with WAsP recommendations [5]) based on EU-DEM data. Height contour lines are then generated with an elevation difference of 5 m between two successive lines.

WAsP is designed for ΔRIX values close to 0, where RIX quantifies the complexity of the elevation model and ΔRIX the difference in complexity between two locations. The validity of the WAsP model is checked according to WAsP recommendations [5], by computing ΔRIX between each wind turbine location and the location of the measurement device used for wind flow simulations.

The ΔRIX values are all equal to 0 for this project, which allows WAsP to be used for wind flow simulations.

4.1.2. Roughness length

Roughness length is a key parameter of the equation that governs wind shear. Changes in roughness length cause variations of wind shear, which propagate vertically as the air flows over the site. The impact at measurement or hub height therefore varies with distance, to roughness changes but is also related to atmospheric conditions.
Given that roughness length is closely related to land use, terrain roughness is modelled using a land-use database. The Sentinel-2 Land Cover (2023) database is used and roughness length values specific to each land use are applied according to 3E's methodology. The validity of the land use areas and of the roughness lengths is checked by comparison to aerial imagery.

The aerial imagery from GeoData dated 2022 is used for this purpose and is assumed representative of the site conditions at the time of writing this report.
The roughness model is adapted so that the land use area shapes fit the aerial imagery.
Following WAsP recommendations, the terrain roughness is modelled within a radius of 20 kilometers.

4.1.3. Large obstacles to the wind flow

Terrain roughness might not properly consider the disturbance of the wind flow caused by tall, isolated obstacles. Such obstacles should therefore be modelled separately. According to WAsP recommendations, isolated obstacles should be modelled separately if they are located within a radius of 50 times their height from any measurement device or wind turbine, and if their height exceeds one third of any measurement or hub height. In this study, no obstacles meet this criterion; hence no obstacle is modelled separately.

4.1.4. Displacement height

When a measurement device or wind turbine is located within or close to a large obstacle (forest, industrial area, urban area, etc.), the wind is blocked and flows over the obstacles. In this case, a displacement height needs to be applied, according to WAsP recommendations.

Applying a displacement height consists in reducing the measurement or hub height by the value of the displacement height. 3E applies a displacement height if an area of obstacles having an average height over 10 m is located within 1 km from any measurement device or wind turbine and obstructs at least one of the twelve 30° sectors. Displacement heights are evaluated following best practices [7].

In this study, the village area located at the center of the island can be considered a large area of obstacles and a displacement height is therefore applied. Table 4 to

Table 6 summarizes the displacement height values applied to each wind turbine.

Table 4: Displacement height – layout 0

Object	Displacement height
[-]	[m]
WT1	0.2

Table 5: Displacement height – layout 1

Object	Displacement height
[-]	[m]
WT1	0.2
WT2	0.3
WT3	1.5

Table 6: Displacement height – layout 2

Object	Displacement height
[-]	[m]
WT1	0.2
WT2	0.5
WT3	0.1

Table 7: Displacement height – layout 3

Object	Displacement height
[-]	[m]
WT1	0.1

Table 8: Displacement height – layout 4

Object	Displacement height
[-]	[m]
WT1	0.1
WT2	0.2
WT3	0.1

4.2. Wind flow model

WAsP is used to extrapolate the wind regime to the location and hub height of each wind turbine. It involves two steps: a vertical extrapolation of the wind regime to hub height and a horizontal extrapolation of the wind regime to each wind turbine location.

4.3. Wind regime at site

The long-term wind regime at 80 m hub height is given as an example, at the location of the wind turbine WT1 in layout 0 in Table 9 and Figure 13.

Table 9: Long-term wind regime at the site

Location	**[-]**	**WT1, layout 0**
Height AGL	[m]	80
Weibull mean wind speed	[m/s]	8.22
Weibull A	[m/s]	9.26
Weibull k	[-]	2.514
Prevailing wind directions	[-]	WSW, W
Wind directions with most energy content	[-]	W, SSW, WSW

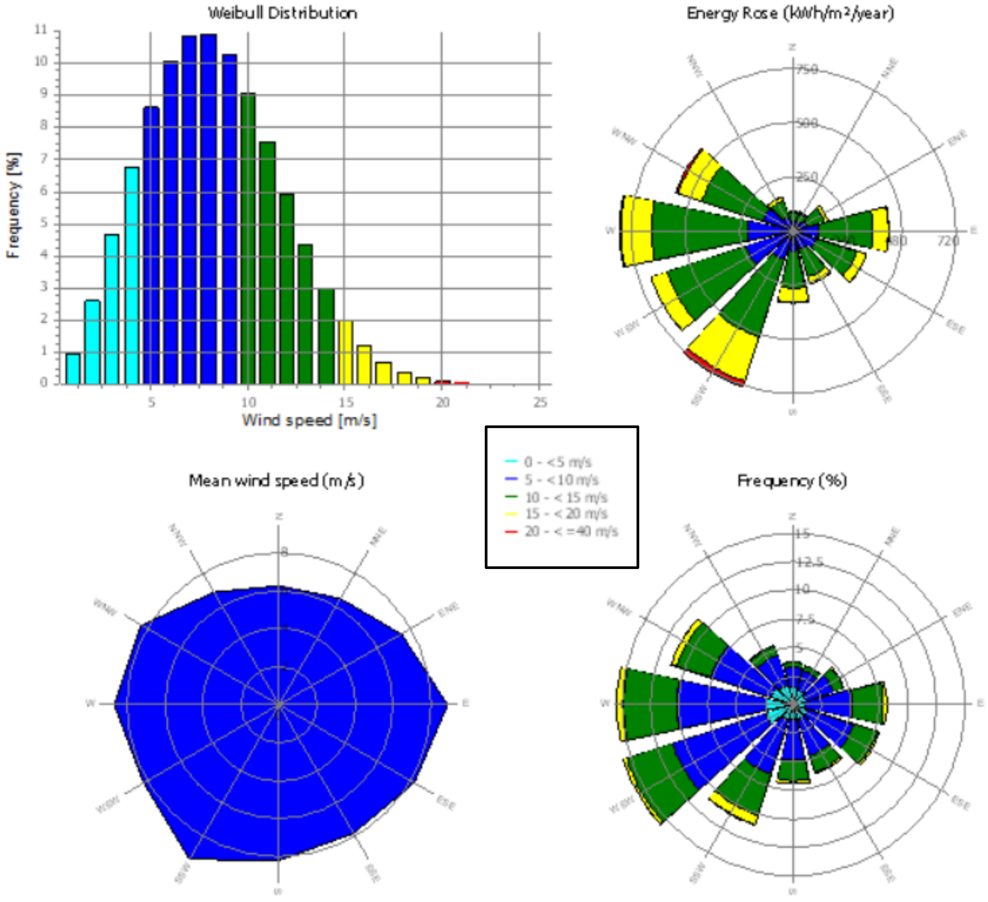

Figure 13: Long-term wind regime at the site

5. Energy Production Losses

5.1. Gross energy production

A gross energy production refers to the theoretical energy production that would be achieved if there was no operational loss. It is calculated by combining the wind regime at a wind turbine location and hub height to the power curve specific to the considered wind turbine type and corrected for local hub height air density. This is done using the software WindPRO. For ease of reading, these results are provided in section 5.3. Power curves are provided in ANNEX D.

Since the energy content of the wind varies proportionally to air density, power curves are adapted accordingly before being used in calculations. The adaptation is done using the new recommended WindPRO method (adjusted IEC 61400-12 method, improved to match turbine control) [8].

For this project, air density at hub height ranges between 1.238 and 1.242 kg/m^3, depending on the wind turbine location and hub height. Air density is calculated by WindPRO based on temperature and pressure measurements from the weather station at Omo, located 31 km from the site and a relative humidity value of 50% according to IEC 61400-12 [3]. According to the experience of 3E, this calculation is accurate enough for the scope of this study.

Important Note: AEP calculation results are specific to the considered wind turbine power curve. Therefore, when procuring the wind turbines for the project, it should be verified that the power curve guaranteed by the manufacturer in the procurement contract corresponds to the one used in this study. Any change to the power curve may require the recalculation of the AEP.

5.2. Energy production losses

5.2.1. General losses

In addition to energy conversion losses considered in the power curve, other losses affect the electrical power expected to be delivered to the grid. The following losses are taken into account in this study and are summarised in Table 10 further below. Other losses may apply but are considered negligible in this study.

5.2.1.1. Turbine interaction losses

Turbine interaction losses are due to the mutual influence of the wind turbines, downstream as well as upstream. The kinetic energy extraction resulting in losses downstream of the turbines are calculated using the N.O. Jensen (PARK2): 2018 wake model. The induction zone leading to a blockage loss upstream of the turbines is estimated with the Forsting self-similarity model. Both models as implemented in WindPRO are used. The influence of existing wind farms is not taken into account in the calculations (cf. section 2.1) since it is supposed that the turbine studied in this project is a replacement of the existing ones.

5.2.1.2. Unavailability losses

Unavailability losses are due to downtime of the wind turbines or balance of plant (maintenance or technical incidents) as well as downtime of the power grid as follows:

- Losses due to maintenance and technical incidents on the turbines are typically evaluated by 3E as 3.0 % of the energy production. This is considered an industry standard but conservative estimate, based on availability guarantees often being around 97 % in operation and maintenance (O&M) contracts.
- Losses due to maintenance and technical incidents on the Balance of Plant (BoP) are typically evaluated by 3E as 0.2 % of the energy production.

- Grid unavailability loss is considered to be 0.3 % for this project. This value is based on the analysis of data from a large portfolio of operational wind farms.

It should be noted that the selected value is not the result of a detailed study and an update might be needed in a later phase of the project.

5.2.1.3. Performance losses

Turbine performance losses are typically due to high wind hysteresis, yaw misalignment, wind flow inclination, turbulence, wind shear and other differences between turbine power curve test conditions and actual conditions at the project site:

- Turbine control limitations correspond to the following losses:
    - High wind hysteresis losses are considered to be negligible for this project for two reasons. Firstly, because the Enercon turbines are equipped with a control mechanism that does not stop the turbine but gradually reduces the output of the turbine, and secondly because the wind distribution at the site is such that this type of event is not likely to occur very often.
    - Sub-optimal turbine performance due to limitations of the turbine system are considered to be 0.2% regardless of the simplicity of the site. This loss is based on the analysis of operational data from a large number of wind farms. It is related to the unwinding of the cables, the configuration of the wind turbine and the physical limits of its control.
- An additional loss of 0.5% is considered in this study, to account for terrain characteristics, which are likely to create non-standard wind flow conditions. This loss is estimated based on 3E's experience.

5.2.1.4. Electrical losses

Electrical losses occur in cables and transformers ensuring electrical transmission to the wind farm substation. 3E typically evaluates them as 1.5 % of the energy production for a wind farm of this size and layout. This value is based on the analysis of data from a large portfolio of operational wind farms.

5.2.1.5. Environmental losses

Environmental losses account for the performance degradation of the wind turbines due to environmental conditions:

- Aerodynamic performance degradation of turbine blades due to dirt accretion (excluding icing) is estimated at 0.25 % for this study,
- Aerodynamic performance degradation of turbine blades due to icing is estimated at 0.2 % for this study,
- Potential turbine shutdowns due to icing conditions are estimated at 0.2 %. This loss is estimated based on the icing frequency calculated from reanalysis data [22]. The

actual loss will highly depend on the icing detection method and the operational strategy which will be applied on the follow-up of icing formation.

- At this stage, 3E does not consider any loss for potential turbine shutdowns due to lighting or hail. If specific shutdown rules are enforced, their impact on production should be evaluated separately.

5.2.2. Curtailment losses

These losses are due to modifications of wind turbine operation for technical or environmental reasons (e.g. related to noise or shadow flicker constraints, birds or bats preservation, etc.). A grid curtailment of 3 MW has been communicated by the Client. Since the turbines maximum power has been set below or equal to this limit. No curtailment losses are applicable.

5.2.3. Losses summary table

The energy production losses defined in the preceding sub-sections are summarised in Table 7.

Important note: some losses taken into account in this study are industry standard values that 3E estimates relevant for the project. They are not all based on contractual documents or specific studies and they should be reviewed for the financial closing of the project.

Table 10: Expected energy production losses (1/2)

Configuration		1x V80, 2 MW @ 80 m	1x V80, 2 MW @ 60 m	1x E82 EP3 E4, 3 MW @ 78 m	1x E82 EP3 E4, 3 MW @ 69 m	1x LWT80, 1.8 MW @ 65 m
Scenario		Layout 0 (i)	Layout 0 (ii)	Layout 0 (iii)	Layout 0 (iv)	Layout 0 (v)
Turbine interaction losses	[%]	0.0	0.0	0.0	0.0	0.0
Unavailability losses	[%]	3.5	3.5	3.5	3.5	3.5
Turbine	[%]	3.0	3.0	3.0	3.0	3.0
BOP	[%]	0.2	0.2	0.2	0.2	0.2
Grid	[%]	0.3	0.3	0.3	0.3	0.3
Performance losses	[%]	0.7	0.7	0.7	0.7	0.7
Non-standard wind flow conditions	[%]	0.5	0.5	0.5	0.5	0.5
Turbine control limitation	[%]	0.2	0.2	0.2	0.2	0.2
Electrical losses	[%]	1.5	1.5	1.5	1.5	1.5
Environmental losses	[%]	0.7	0.7	0.7	0.7	0.7
Performance degradation not due to icing	[%]	0.3	0.3	0.3	0.3	0.3

Configuration		1x V80, 2 MW @ 80 m	1x V80, 2 MW @ 60 m	1x E82 EP3 E4, 3 MW @ 78 m	1x E82 EP3 E4, 3 MW @ 69 m	1x LWT80, 1.8 MW @ 65 m
Scenario		Layout 0 (i)	Layout 0 (ii)	Layout 0 (iii)	Layout 0 (iv)	Layout 0 (v)
Performance degradation due to icing	[%]	0.2	0.2	0.2	0.2	0.2
Shutdown due to icing	[%]	0.2	0.2	0.2	0.2	0.2
Curtailment losses	**[%]**	0.0	0.0	0.0	0.0	0.0
Total losses	**[%]**	6.3	6.3	6.3	6.3	6.3

Table 11: Expected energy production losses (2/2)

Configuration		3x V52, 0.85 MW @ 55 m	3x V52, 0.85 MW @ 55 m	1x V80, 2 MW @ 60 m	3x V52, 0.85 MW @ 55 m
Scenario		Layout 1	Layout 2	Layout 3	Layout 4
Turbine interaction losses	[%]	0.1	1.5	0.0	0.9
Unavailability losses	[%]	3.5	3.5	3.5	3.5
Turbine	[%]	3.0	3.0	3.0	3.0
BOP	[%]	0.2	0.2	0.2	0.2
Grid	[%]	0.3	0.3	0.3	0.3
Performance losses	**[%]**	0.7	0.7	0.7	0.7
Non-standard wind flow conditions	[%]	0.5	0.5	0.5	0.5
Turbine control limitation	[%]	0.2	0.2	0.2	0.2
Electrical losses	**[%]**	1.5	1.5	1.5	1.5
Environmental losses	**[%]**	0.7	0.7	0.7	0.7
Performance degradation not due to icing	[%]	0.3	0.3	0.3	0.3
Performance degradation due to icing	[%]	0.2	0.2	0.2	0.2
Shutdown due to icing	[%]	0.2	0.2	0.2	0.2
Curtailment losses	**[%]**	0.0	0.0	0.0	0.0
Total losses	**[%]**	6.3	7.7	6.3	7.1

(*) The production losses in % are combined as: $\boldsymbol{Total} = 100 - \frac{\prod_i (100 - \boldsymbol{Loss}_i)}{100^{(N-1)}}$

5.3. Net energy production

Energy production losses are applied to the expected annual gross energy production, resulting in the expected net Annual Energy Production (AEP).

The expected AEP and other energy production figures are presented in Table 12. For each configuration, the following results are provided:

- Gross energy production: corresponds to the theoretically recoverable annual energy production at the outlet side of the generator, without production losses.
- Energy production losses: as computed in Section 5.

- Net energy production (AEP): corresponds to the annual energy production expected to be delivered to the grid (taking into account all energy production losses).
- Net full load equivalent hours: is the amount of time it would take for the wind farm to yield its annual production if it was able to constantly produce at full load.
- Net capacity factor: is the net full load equivalent hours divided by the total number of hours in a year. It represents the usage of the installed capacity.

Table 12: Expected wind farm energy production figures (1/2)

Configuration		**V80, 2 MW @ 80 m**	**V80, 2 MW @ 60 m**	**E82 EP3 E4, 3 MW @ 78 m**	**E82 EP3 E4, 3 MW @ 69 m**	**LWT80, 1.8 MW @ 65 m**
Scenario		Layout 0 (i)	Layout 0 (ii)	Layout 0 (iii)	Layout 0 (iv)	Layout 0 (v)
Gross energy production	[MWh/y]	7,574	6,702	9,182	8,700	6,618
Wake losses	[%]	0.0	0.0	0.0	0.0	0.0
Curtailment losses	[%]	0.0	0.0	0.0	0.0	0.0
Other losses	[%]	6.3	6.3	6.3	6.3	6.3
Total energy production losses	[%]	6.3	6.3	6.3	6.3	6.3
Net energy production (AEP)	**[MWh/y]**	**7,100**	**6,283**	**8,608**	**8,156**	**6,204**
Net full load equivalent hours	[h/y]	3,550	3,142	2,869	2,719	3,447
Net capacity factor	[%]	40.5	35.8	32.7	31.0	39.3

Table 13: Expected wind farm energy production figures (2/2)

Configuration		**V52, 0.85 MW @ 55 m**	**V52, 0.85 MW @ 55 m**	**V80, 2 MW @ 60 m**	**V52, 0.85 MW @ 55 m**
Scenario		**Layout 1**	**Layout 2**	**Layout 3**	**Layout 4**
Gross energy production	[MWh/y]	8,256	8,331	7,430	8,617
Wake losses	[%]	0.1	1.5	0.0	0.9
Curtailment losses	[%]	0.0	0.0	0.0	0.0
Other losses	[%]	6.3	6.3	6.3	6.3
Total energy production losses	[%]	6.3	7.7	6.3	7.1
Net energy production (AEP)	**[MWh/y]**	**7,732**	**7,692**	**6,966**	**8,003**
Net full load equivalent hours	[h/y]	3,032	3,016	3,483	3,138
Net capacity factor	[%]	34.6	34.4	39.7	35.8

6. Conclusion

3E has calculated the expected energy production and the associated uncertainties for the 9 proposed configurations of the Fejo wind farm project. The main production results expected for a 20-year period are summarised in the following table:

Table 14:: 20 year expected AEP (1/2)

Configuration		**V80, 2 MW @ 80 m**	**V80, 2 MW @ 60 m**	**E82 EP3 E4, 3 MW @ 78 m**	**E82 EP3 E4, 3 MW @ 69 m**	**LWT80, 1.8 MW @ 65 m**
Scenario		Layout 0 (i)	Layout 0 (ii)	Layout 0 (iii)	Layout 0 (iv)	Layout 0 (v)
Gross energy production	[MWh/y]	7,574	6,702	9,182	8,700	6,618
Total energy production losses	[%]	6.3	6.3	6.3	6.3	6.3
Net energy production (AEP)	**[MWh/y]**	**7,100**	**6,283**	**8,608**	**8,156**	**6,204**
Net full load equivalent hours	[h/y]	3,550	3,142	2,869	2,719	3,447

Table 15:: 20 year expected AEP (2/2)

Configuration		**V52, 0.85 MW @ 55 m**	**V52, 0.85 MW @ 55 m**	**V80, 2 MW @ 60 m**	**V52, 0.85 MW @ 55 m**
Scenario		Layout 1	Layout 2	Layout 3	Layout 4
Gross energy production	[MWh/y]	8,256	8,331	7,430	8,617
Total energy production losses	[%]	6.3	7.7	6.3	7.1
Net energy production (AEP)	**[MWh/y]**	**7,732**	**7,692**	**6,966**	**8,003**
Net full load equivalent hours	[h/y]	3,032	3,016	3,483	3,138

Important notes:

- It should be noted that 3E assumes that any information communicated by the client is correct.
- Results of AEP calculations are specific to the curtailment strategies taken into account in this study. Any change to these curtailment strategies will require the recalculation of AEP.
- Several energy production losses taken into account in this study are industry standard values that 3E estimates relevant for the project. They are not all based

on contractual documents or specific studies and they should be reviewed for the financial closing of the project.

7. Other considerations and recommendations

This study is a preliminary stage study. For further stages of the project development, it is advised that more detailed studies are performed, including the ones listed below:

- A detailed study of the legal framework applicable to wind farms in Denmark and a verification of the information provided for this report. In particular, the legislation that applies to Natura 2000 zones has to be further investigated.
- An environmental impact study, in order to establish whether specific animal species should be taken into account such as birds and bats, resulting in curtailments of the turbines.
- A noise study for the specific chosen configuration, in order to determine the requirement of noise curtailments plans.
- Eventually, depending on the turbines location, a shadow impact study should also be executed.
- Financial assessment of the preferred solution(s) and evaluation – together with manufacturers - of whether refurbished turbines could be implemented in the specific territorial context.

In addition to the above, relevant topics which are out of the key scope of this report but that have been crossed during the project execution by the Secretariat are the ones of grid connection and logistics.

7.1. Energy balance

The Island transition team has communicated a current electricity consumption (2023) of 3.15 GWh/year, of which 2.83 GWh/year imported from the mainland (main power connection is with Lolland) and 0.32 GWh produced on Fejo. Also, the Island transition team estimated that a fully electrified island (incl. land and marine transport) would require a total of 5.85 GWh/year.

This would mean that, in all the assessed scenarios, **the wind farm production will be higher than the expected total consumption on a yearly basis**, transforming Fejo into a net exporter of electricity.

Independently of the studied scenarios and configurations, it is also to be noticed that:

- **1 x V52 850kW** at any of the assessed locations (least efficient WTG in Layouts 1-2-4) would be sufficient to reach – on an annual basis and including also the pre-existing power production on the island – a minimum **self-sufficiency level of approx. 89% with respect to the current power consumption**.

- **2 x V52 850kW** at any of the assessed locations (2 least efficient WTGs in 1-2-4) would be sufficient to reach – on an annual basis and including also the pre-existing power production on the island – a minimum **self-sufficiency level of approx. 92% with respect to the expected power consumption with a fully electrified island**.

For the above reasons, it is suggested to take into consideration the **implementation of a stepwise project**, with one wind turbine to be realised in the short-term, and the other(s) to be included at a later stage, along with the progressive electrification of consumption.

7.2. Grid connection

3E contacted Cerius (local DSO) in order to get a preliminary screening on the feasibility of the project implementation from the point of view of the grid connection. 3E question concerned a full repowering intervention of the WTG in Skalo.

Cerius feedback is summarised as follows:

- If the 55 kW WTG in Skalo is dismissed and 150 kW WTG in Osterby is kept for production:
    - The 55 kW WTG at Skalo can be repowered to maximum 300 kW in current connection point station 3276 at Skalo;
      OR
    - A new WTG of maximum 500 kW can be connected in a station near Vesterby (to be located anywhere but with a power cable up to station to be paid by the project proposer).
- If both the current WTG are dismissed, then:
    - Either Skalø WTG can be repowered in the current connection point to 400 kW;
      OR
    - A new WTG of maximum of 700 kW can be connected in a station near Vesterby (to be located anywhere but with a power cable up to station to be paid by the project proposer).

Therefore, **the maximum possible connection capacity without grid reinforcements amounts to approx. 650-700 kW**. Larger solutions – as the ones required by the Client and studied in this report – need to be provided as specific cases for which the required grid reinforcements will need to be assessed. Larger installed capacities might lead, depending on the costs for the cheapest alternative, to:

- Reinforcement of the existing grid and sea cable to Lolland by Cerius;
  OR
- Connection point at the nearest station where capacity is sufficient on Lolland, with sea cable to be established at the customer expenses.

Cerius should be then contacted to further assess in detail a specific configuration and provide the connection solution. It is highlighted how the possible need to establish a sea cable at the Client expense might cause a large increase of the required investment cost.

On top of any cable to the power station identified by Cerius in its connection solution, the project proposer will also be required to pay a connection fee amounting to:

- Connection to LV ("Blav", Low Voltage) at 400 V: kr. 2.799.000,- per MVA (MW divided by 0.95). Transformer is supplied by Cerius.
- Connection to MW ("Bhøj", Medium Voltage) at 10 kV: kr. 2.251.000,- per MVA (MW divided by 0.95). The transformer needs to be supplied by the project proposer.

7.3. Logistics

Because of Fejo's peculiarities, the project execution may require the implementation of non-conventional transport of overloaded (nacelle/drivetrain and hub) and oversized (turbine blades and tower sections) equipment.

Depending on the chosen location for the WTG, different options could be compared:

- Transport of oversized and overloaded equipment via ferry at the port of Vesterby. Key elements to be further assessed:
    - Suitability of the ferry currently in operation between Fejo and Lolland in transporting trucks with oversized and overloaded loads.
    - Suitability of Vesterby port area in unloading trucks with such equipment.
    - Swept path analysis for the transport of oversized equipment through the inhabited areas. Possible interference with other obstacles incl. streetlamps and vegetation.
- Unloading of trucks transporting the equipment through beach landing via dedicated ships (possibly preferred options for installations in Skalo and Osterby, due to the long path from Vesterby port through inhabited areas). Key elements to be further assessed:
    - Suitability of the bathymetry profile to such a beach landing.
    - Expected impact on marine flora and fauna and best tide and period of the year to execute the beach landing.

It is recommended that, once the Island transition team will have identified the preferred configuration, this topic is analysed together with the wind turbine manufacturer / provider, which may have experience with logistic operations in similar territorial contexts.

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ANNEX A SITE DESCRITION ILLUSTRATIONS

Figure 14: site environment

Figure 15: Site elevation (contour lines every 5 metres, and wormer colours denote higher elevations)

ANNEX B WIND TURBINE COORDINATES

Table 16: Wind turbine coordinates configuration for layout 0 (ETRS-TMzn Pan-European Transverse Mercator (UTM)-ETRS89 Zone: 32)

Turbine	Longitude (X)	Latitude (Y)	Altitude
WT1	657,006	6,092,299	5

Table 17: Wind turbine coordinates configuration for layout 1 (ETRS-TMzn Pan-European Transverse Mercator (UTM)-ETRS89 Zone: 32)

Turbine	Longitude (X)	Latitude (Y)	Altitude
WT1	657,006	6,092,299	5
WT2	655,490	6,091,311	0
WT3	652,459	6,091,548	5

Table 18: Wind turbine coordinates configuration for layout 2 (ETRS-TMzn Pan-European Transverse Mercator (UTM)-ETRS89 Zone: 32)

Turbine	Longitude (X)	Latitude (Y)	Altitude
WT1	657,006	6,092,299	5
WT2	656,857	6,092,678	9
WT3	657,277	6,092,123	5

Table 19: Wind turbine coordinates configuration for layout 3 (ETRS-TMzn Pan-European Transverse Mercator (UTM)-ETRS89 Zone: 32)

Turbine	Longitude (X)	Latitude (Y)	Altitude
WT1	650,531	6,093,689	2

Table 20: Wind turbine coordinates configuration for layout 4 (ETRS-TMzn Pan-European Transverse Mercator (UTM)-ETRS89 Zone: 32)

Turbine	Longitude (X)	Latitude (Y)	Altitude
WT1	650,531	6,093,689	2
WT2	657,006	6,092,299	5
WT3	657,277	6,092,123	5

ANNEX C THE WASP MODEL

The central point in the wind transformation model of WAsP – the so-called Wind Atlas Methodology – is the concept of a Regional or Generalized Wind Climate, or Wind Atlas. This Generalized Wind Climate is the hypothetical wind climate for an ideal, featureless and completely flat terrain with a uniform surface roughness, assuming the same overall atmospheric conditions as those of the measuring position. The basic "machine" of WAsP is a flow model, representing the effect of different terrain features:

- Terrain height variations,
- Terrain roughness,
- Sheltering obstacles.

To deduce the Generalized Wind Climate from measured wind in actual terrain, the WAsP flow model is used to remove the local terrain effects.

To deduce the wind climate at a location of interest from the Generalized Wind Climate, the WAsP flow model is used to introduce the effect of terrain features.

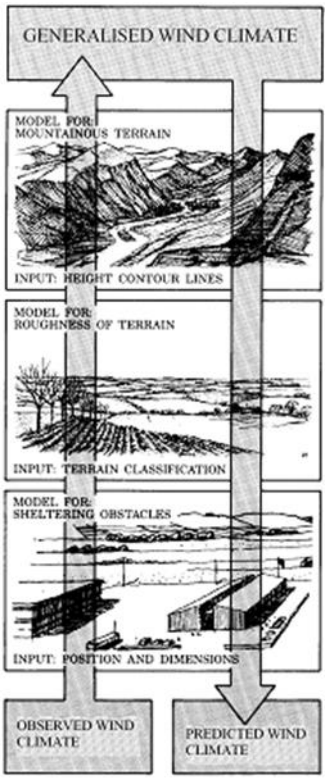

Figure 16: Wind Atlas methodology (Source: wasp.dk)

ANNEX D Power & Thrust Curves

Table 21: Power & thrust curves (PC & TC), air density = 1.225 kg/m^3 [23][25]

Wind speed	V80 2MW		E82 EP3 E4 3MW	
	PC	TC	PC	TC
[m/s]	[kW]	[-]	[kW]	[-]
3	-	-	25	1.000
3.5	-	-	50	1.000
4	53	0.874	82	0.980
4.5	93	0.859	122	0.930
5	143	0.853	174	0.950
5.5	201	0.849	240	0.950
6	272	0.848	321	0.960
6.5	355	0.847	415	0.960
7	452	0.848	525	0.960
7.5	563	0.847	654	0.960
8	690	0.843	800	0.950
8.5	830	0.832	961	0.940
9	983	0.813	1,135	0.930
9.5	1,145	0.789	1,320	0.890
10	1,311	0.752	1,510	0.860
10.5	1,477	0.708	1,700	0.820
11	1,635	0.657	1,880	0.790
11.5	1,773	0.600	2,045	0.770
12	1,876	0.538	2,200	0.740
12.5	1,938	0.474	2,350	0.720
13	1,972	0.415	2,500	0.700
13.5	1,994	0.363	2,647	0.670
14	1,999	0.320	2,770	0.550
14.5	2,000	0.283	2,852	0.470
15	2,000	0.254	2,910	0.410
15.5	2,000	0.229	2,961	0.360
16	2,000	0.207	3,000	0.320
16.5	2,000	0.188	3,017	0.290
17	2,000	0.171	3,020	0.260
17.5	2,000	0.157	3,020	0.240
18	2,000	0.144	3,020	0.220
18.5	2,000	0.133	3,020	0.200
19	2,000	0.123	3,020	0.180
19.5	2,000	0.114	3,020	0.170
20	2,000	0.106	3,020	0.150
20.5	2,000	0.098	3,020	0.140
21	2,000	0.092	3,020	0.130
21.5	2,000	0.086	3,020	0.120
22	2,000	0.080	3,020	0.120
22.5	2,000	0.075	3,020	0.110
23	2,000	0.071	3,019	0.100
23.5	2,000	0.067	3,014	0.100
24	2,000	0.063	3,002	0.100
24.5	2,000	0.059	2,980	0.090
25	2,000	0.056	2,947	0.080
25.5	-	-	2,895	0.080
26	-	-	2,824	0.070
26.5	-	-	2,731	0.070
27	-	-	2,615	0.060

27.5	–	–	2,488	0.060
28	–	–	2,178	0.050
28.5	–	–	1,952	0.050
29	–	–	1,752	0.040
29.5	–	–	1,553	0.040
30	–	–	1,357	0.030
30.5	–	–	1,195	0.030
31	–	–	1,024	0.020
31.5	–	–	861	0.020
32	–	–	712	0.020
32.5	–	–	616	0.010
33	–	–	499	0.010
33.5	–	–	395	0.010
34	–	–	307	0.010

Table 22: Power & thrust curves (PC & TC), air density = 1.225 kg/m³ [24][26]

Wind speed	**V52 0.85 MW**		**LWT80 1.8 MW**	
	PC	TC	PC	TC
[m/s]	[kW]	[-]	[kW]	[-]
2	–	–	2	0.000
3	0	3	59	0.772
4	26	4	145	0.778
5	67	5	263	0.781
6	125	6	440	0.783
7	203	7	677	0.783
8	304	8	946	0.784
9	425	9	1,256	0.784
10	554	10	1,554	0.785
11	671	11	1,775	0.729
12	759	12	1,800	0.488
13	811	13	1,800	0.363
14	836	14	1,800	0.283
15	846	15	1,800	0.227
16	849	16	1,800	0.186
17	850	17	1,800	0.155
19	850	19	1,800	0.133
20	850	20	1,800	0.116
21	850	21	1,800	0.103
22	850	22	1,800	0.092
23	850	23	1,800	0.082
24	850	24	1,800	0.075
25	850	25	1,800	0.068

ANNEX E DETAILED PRODUCTION PER TURBINE

This section details the production per turbine for the configurations that contain more than a single turbine.

Table 23: Detailed production per turbine Layout 1

Configuration	Layout 1	Total	WT1	WT2	WT3
Gross energy production	[MWh/y]	**8,256**	2,744	2,682	2,829
Wake losses	[%]	**0.1**	0.2	0.1	0.0
Curtailment losses	[%]	**0.0**	0.0	0.0	0.0
Other losses	[%]	**6.3**	6.3	6.3	6.3
Total energy production losses	[%]	**6.3**	6.4	6.3	6.3
Net energy production (AEP)	**[MWh/y]**	7,732	**2,568**	**2,512**	**2,651**
Net full load equivalent hours	[h/y]	**3,032**	3,021	2,956	3,119
Net capacity factor	[%]	**34.6**	34.5	33.7	35.6

Table 24: Detailed production per turbine Layout 2

Configuration	Layout 2	Total	WT1	WT2	WT3
Gross energy production	[MWh/y]	**8,331**	2,742	2,798	2,791
Wake losses	[%]	**1.5**	1.7	1.0	1.8
Curtailment losses	[%]	**0.0**	0.0	0.0	0.0
Other losses	[%]	**6.3**	6.3	6.3	6.3
Total energy production losses	[%]	**7.7**	7.9	7.2	8.0
Net energy production (AEP)	**[MWh/y]**	7,692	**2,525**	**2,598**	**2,569**
Net full load equivalent hours	[h/y]	**3,016**	2,971	3,056	3,022
Net capacity factor	[%]	**34.4**	33.9	34.9	34.5

Table 25: Detailed production per turbine Layout 4

Configuration	Layout 4	Total	WT1	WT2	WT3
Gross energy production	[MWh/y]	**8,617**	3,086	2,743	2,789
Wake losses	[%]	**0.9**	0.0	1.3	1.6
Curtailment losses	[%]	**0.0**	0.0	0.0	0.0
Other losses	[%]	**6.3**	6.3	6.3	6.3
Total energy production losses	[%]	**7.1**	6.3	7.5	7.8
Net energy production (AEP)	**[MWh/y]**	8,003	**2,892**	**2,538**	**2,572**
Net full load equivalent hours	[h/y]	**3,138**	3,403	2,986	3,026
Net capacity factor	[%]	**35.8**	38.8	34.1	34.5